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(54) A capability predictor

(57) A capability predictor that comprises a database 15 of capability of multiple designs is disclosed. The process capability data includes costs, quality, cycle time, and performance models. The process owner (expert) provides the data. The developer inputs equations necessary to calculate the predictions based in the selected design characteristics and the user selects the design. A processor 11 calculates the prediction based on the selected design and a display, such as monitor 11a or printer 16, displays the results of the predictions.

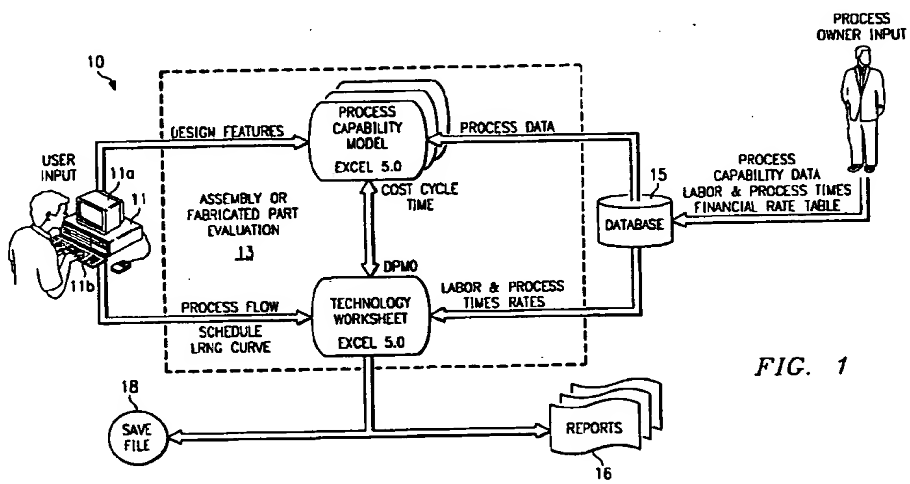

FIG. 1

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Descripti n

FIELD OF THE INVENTION

This invention relates to a method and apparatus to predict the capability of a design or process.

BACKGROUND OF THE INVENTION

Design and manufacturing cycles in the prior art have included several product redesign iterations to minimize the manufacturing product costs and cycle times and maximize the product quality. This process is very costly and time consuming. Today's competitive market requires minimum product manufacturing costs and high product quality with minimum time to market cycle.

Over the past few years, quality has been addressed with process capability tools such as SSDR (Six Sigma Design Review) and Process Capability Library (PCL). The SSDR tool was developed at Texas Instruments and has been used and published by the International Casting Institute.

The PCL is a process capability tool for quality analysis. This is described in U. S. Patent no. 5,452,218 of Tucker, et al. Entitled "System and Method for Determining Quality Analysis of Fabrication and/or Assembly Design Using Shop Capability Data", issued September 19, 1995.

SUMMARY OF THE INVENTION

In accordance with one embodiment of the present invention, a capability predictor comprises a database of capability data of multiple characteristics, an interactive input means for selecting characteristics, a computer processor responsive to said selected characteristics and according to prediction algorithm for generating signals representing capability prediction.

DESCRIPTION OF THE DRAWINGS

These and other features of the invention will be apparent to those skilled in the art from the following detailed description of the invention, taken together with the accompanying drawings.

Fig. 1 is a block diagram of the system according to one embodiment of the present invention;

Fig. 2 illustrates quality model data flow;

Fig. 3 is an Excel Spreadsheet illustrating a sample model for a wire stripe process;

Fig. 4 is a technology worksheet using Excel;

Fig. 5 illustrates cost model data flow according to one embodiment of the present invention;

Fig. 6 illustrates time determination for a process based on feature dependencies;

Fig. 7 is a technology worksheet with a user defined input;

Fig. 8 is a program cover sheet with a manufacturing profile;

Fig. 9 is a technology worksheet with labor cost detail with applied overhead;

Fig. 10 is a technology worksheet with labor cost detail in hours per unit;

Fig. 11 illustrates cycle time model data flow;

Fig. 12 is a technology worksheet with cycle time detail;

Fig. 13 illustrates a technology worksheet with completed user input;

Fig. 14 illustrates information input flow in accordance to a second embodiment of the present invention;

Fig. 15 illustrates a primary technology screen according to a second embodiment of the present invention;

Fig. 16 illustrates a part type menu screen;

Fig. 17 illustrates a machine part surfaces screen;

Fig. 18 illustrates a machined part holes screen;

Fig. 19 illustrates an alodine finish process screen;

Fig. 20 illustrates another anodize finish process screen;

Fig. 21 illustrates a passivate finish process screen;

Fig. 22 illustrates a plating finish process screen;

Fig. 23 illustrates a painting finish process screen;

Fig. 24 illustrates a mask/demask finish process screen;

Fig. 25 illustrates a marking finish process screen;

Fig. 26 illustrates a heat treat finish process screen;

Fig. 27 illustrates a cylindrical part surface screen;

Fig. 28 illustrates a sheet metal feature screen;

Fig. 29 illustrates an assembly input screen;

Fig. 30 illustrates a second manual input screen; and

Fig. 31 is a graph of values for the rate (y-axis) versus input values (x-axis).

DESCRIPTION OF PREFERRED EMBODIMENTS

Each individual design dictates the majority of all manufacturing costs quality and cycle time. To make a significant impact on these metrics, the designer must understand the interrelationship among product design characteristics, manufacturing costs, quality, cycle time, and design function trade-offs. The present invention is a method and apparatus to interactively determine the manufacturing cost, quality, and cycle time of a design based on product design characteristics.

Referring to Fig. 1 there is illustrated a block diagram of the system according to the present invention. The components include a processor 11 including a computer 11 and display 11a with a keyboard 11b and mouse input 11d which may be, for example, an Intel Pentium processor or an Intel 486 processor or equivalent. The system further includes a windows program such as Windows 3.1 or Windows `95 operating system. The system may also be a UNIX workstation. The system also includes, for example, a Microsoft Excel 5.0 or other spreadsheet or database software package like Lotus 1-2-3. The system, as discussed previously, includes a database 15 which stores the process capability data which includes costs, quality, and cycle time models. The system may also include Access 2.0 database software and a software interface. The system 10 may include a printer display 16 for printing reports. The reports may also be stored on a file 18 and accessed by the computer 11 and displayed on a display or if connected to a network display on another computer terminal or printer.

The program in the computer 11, for example, generates screens such as Excel screens for the model builder and for the user. The screens request inputs from the model builder and user for generating the database and/or models. For the model builder, the builder inputs the feature, the quantity factor such as DPMO, cost, and cycle time, with a heading of the sources name and address. A table is made up for each technology and filled out by the model builder. For the user's screens, for example, for a given technology, the quality factor such as DPMO, cost, and cycle time are presented for each feature for a given selected technology. The software developer puts behind the appropriate cells the equations necessary to calculate, for the user, the DPMOs for the selected design characteristics, the cycle time, and the cost. The models are the process quality or dpmo prediction model, the manufacturing process cost prediction

model, and a manufacturing process cycle time prediction model. In the descriptions that follow, the following nomenclature is used:

Product Quality - Defects per Unit (DPU)

DPU_{scrap} -- Scrap causing defects per unit for a process

DPU_{rework} -- Repairable defects per unit for a process

Process Capability -- Defects per Million Opportunities (dpmo)

Opportunity -- The opportunity in a design to create or incorporate a manufacturing defect

Cost -- The labor and overhead costs incurred in the manufacture of a particular product design.

HPU -- Manufacturing labor in hours per unit

FTY -- First pass inspection yield for a process in percent

Total Hours per Unit -- manufacturing labor hours per unit plus defect repair and rework labor hours

True Lot Midpoint (TLMP) -- The manufactured unit which theoretically represents the average cost of a lot quantity of manufactured units

Cycle Time -- The total time a product in the manufacturing cycle from raw material to finished product

%NVA -- (percent non-value added) the percent of the total hours per unit spent in manufacturing repair and/or rework operations.

Attributes Data -- Process defects are identified using go/no-go or good/bad quality criteria.

LO -- Labor and Overhead

DPMO Range -- The full range of defect rates experienced in the manufacturing process.

BC DPMO -- Best Case DPMO, the lower of the two end points of the DPMO range.

WC DPMO -- Worst Case DPMO, the highest of the two end points of the DPMO range.

The manufacturing process quality capability data, the manufacturing cost capability data, and the manufacturing cycle time data is entered by a process owner and stored in the database 15. This may be by the same computer terminal or a separate computer terminal coupled to the database 15 as shown in system in cited Patent 5,452,218 where PC Telnet or a SUN workstation interfaces to the data file in a file server via a LAN.

Referring to Fig. 2, there is illustrated the data flow of a quality predictor using the quality process capability model. The user and process owner (expert) inputs to the model are shown at the left and outputs are provided as shown at the right in Fig. 2. The model calculations are depicted with the equations and the transform boxes between the inputs and outputs. The feature weights and feature characteristic ratings are input by the process owners and the feature picks by the user. The score is calculated by the transform equations represented by blocks 21 and 22, where each feature is scored at the appropriate spreadsheet cell location represented by block 21 and summed (block 22) and put in the totals block. The DPMO range is input by the process owner (expert) with minimum for minimum DPMO and a maximum DPMO for maximum anticipated for lowest score. The transform equation (block 23) reads the DPMO range and the score in block 22 and generates the predicted DPMO. The outputs at the right are displayed on the screens.

A team of process experts analyzes the process output data for a substantial production period and develops a design feature predictive model of the process. The accuracy and precision of the model is determined by the quantity and quality of the defect data reviewed. The model can be as precise as a historical regression model if the defect can be mapped to a design feature and there is sufficient data to generate high confidence levels. Because very few manufacturing shops keep a detailed catalog of historical defect data, an engineering estimate is used to further develop a first order process model, which is refined over time as more process data is collected and analyzed by the process expert team.

The process owner inputs the model header information such as process consultant, phone number of consultant, and mail station, and the process name and with a brief description. The process owner/expert team then describes the predictive model using product design features and characteristics.

The model user selects the product feature characteristics that best describe the design along with the number of times the characteristics appear in the design. Fig. 3 illustrates on an Excel spreadsheet a sample model for the wire stripe process. This is for a single conductor wire for striping. When a wire for a harness is purchased it is usually white and the first step is to color code the wire by striping it to distinguish from other wires in a harness. The example of Fig. 3 relates to this process. A model is built for each process with data. The process owner as shown in Fig. 2 inputs the feature weights and feature characteristic rating and the user picks the features and characteristics. The user design selections are depicted by the black dots next to the design characteristic. The process owners provide the key features that drive most of the defects rate. In this case, they determine jacket material, wire gauge, length of conductor and number of the conductors to be significant, as shown in Fig. 3. Another input by the process owner is how big a driver is the feature. Jacket material drives 60% of the defect output of that process so it is given a higher weighting. The rating number is a relative number with a rating of 1 being the best, resulting in the fewest defects. All selections are rated. The rating times the weight gives the score. The scores are totaled and put on total scores 0.61. The score of 1.00 would be a perfect score where ratings are all 1's. The different jacket types have their own benefits. In the example, Teflon (ptfe) is selected. With a score of 0.61 the DPMO is 9,015. The process DPMO range is 230 to 22750. If the total score were 1.00 the DPMO would be 230.

In Fig. 2, the predicted DPMO in the output is calculated by the equation of block diagram 23 using the design score from block 22 and the input DPMO range placed by the expert. The equation is predicted DPMO = (1-score)(DPMO range) + BCDPMO . This equation for Excel is associated with the cell location for DPMO in the worksheet.

The DPMO prediction confidence interval is based on the quantity and quality of process observations available to the process owner. If little or poor quality process actual data exists, the confidence interval for a prediction can be as simple as the percentage (%) range DPMO about the predicted mean expected by the process owner. If sufficient, high quality data is available to the process owner, the process DPMO confidence interval can be determined using the equations shown in block 25 of Fig. 2 or $(+/- 1.65)(\sqrt{(p)(1-p/n)})$, where p is the probability of a defect and n is the number of actual data points. The appropriate calculation methodology is chosen and maintained in the Process Capability Model (PCM) by the process owner. The prediction confidence interval is displayed to the user on the printed evaluation report output.

The tool is interactive in that the user sees the results of his/her selections in real time and can make changes if a desired result is not achieved in the design characteristic selections. The user then accepts the model to his/her technology worksheet and proceeds to the next process or design feature.

The quality model output is a process DPMO value (9015) for the product design feature characteristic selections and it is transferred to the technology worksheet in location I11 (column, row) as shown in Fig. 4.

A flow block diagram of the cost predictor model is shown in Fig. 5. The user and process owner inputs to the model are shown on the left and the outputs are shown on the right. The inputs are predicted DPMO (calculated above), Design Quantity and Process Opportunities, scrap rate, rework hours, build hours, learning curve and total units and rates. The design quantity is used for generating total opportunities and theoretical HPU (hours per unit). The DPMO is generated by the quality model and is used to predict the total DPU. The model calculations that occur in each data transformation blocks 51-66 are numbered and can be found in the equation Table I below.

51. Total Opportunities = Process Opportunities × Design Quantity
52. Total DPU = Total Opportunities × dpmo ÷ 1,000,000
53. Scrap DPU = Total DPU × Scrap Rate
54. Rework DPU = Total DPU - Scrap DPU
55. $\text{Yield}_{scrap} = e^{-\text{DPU}_{scrap}}$
56. Rework HPU = Rework Hours $\times \text{DPU}_{rework}$
57. Scrap HPU = Build Hours × $(1 - \text{Yield}_{scrap})$
58. Theoretical HPU = Build Hours × Design Quantity
59. Total HPU = Rework HPU + Scrap HPU + Theoretical HPU
60. HPU at TLMP = Total HPU × (Unit_{TLMP} /Unit Basis)^((LOG(Learning Curve))/LOG(2));
where Unit_{TLMP} =
((((Total Learned Units+0.5)^(1+(LN(Learning Curve)/LN(2))))
-(0.5^(1+(LN(Learning Curve)/LN(2)))))/((1+(LN(Learning Curve)
/LN(2)))*(Total Learned Units)))^(1/(LN(Learning Curve)/LN(2)))

61. Rework Cost = Rework HPU × Labor Rates
62. Scrap Cost = Scrap HPU × Labor Rates
63. Theoretical Cost = Theoretical HPU × Labor Rates
64. Total Cost = Rework Cost + Scrap Cost + Theoretical Cost
65. Cost at TLMP = Total Cost × (Unit_{TLMP} /Unit Basis)^((LOG(Learning Curve))/LOG(2));
where Unit_{TLMP} =
((((Total Learned Units+0.5)^(1+(LN(Learning Curve)/LN(2))))
-(0.5^(1+(LN(Learning Curve)/LN(2)))))/((1+(LN(Learning Curve)
/LN(2)))*(Total Learned Units)))^(1/(LN(Learning Curve)/LN(2)))

66. Percent NVA = ((Rework Cost + Scrap Cost)/ Total Cost) ×100

TABLE I. COST MODEL EQUATIONS

Theoretical Cost

Theoretical cost is defined as the cost associated with a particular process or event, running from start to finish, with no defects. Theoretical cost is determined by the touch labor time required to initiate and complete the process of building a unit of product and then apply the appropriate labor pay rate and factory overhead rate.

The touch labor time for the theoretical build process is separated into two components; the time to set-up for the process, and the run time needed to complete the process. The total set-up time is amortized over the number of units processed for a single set-up -- the run size. That is to say, for example, that if the process set-up allows multiple units to be prepared (fixtured, loaded in a machine, etc.) for the event of processing, then the time for set-up is divided by that number of units prepared. Run time is the observed or estimated time for processing a unit. Processing, in this context, refers to the actual act of physically changing or adding to a unit of product. The theoretical build time for the process step, then, includes the sum of the proportioned amount of set-up time plus the actual processing time multiplied by the process quantity.

Therefore,

$$\text{Theoretical Cost (LO)} = ((\text{Build Set-up Time} \div \text{Run Size}) + (\text{Build Run Time} \times \text{Quantity}) \times (\text{Labor Rate} \times (1 + \text{Labor Overhead}))$$

The theoretical build cost may vary depending on the features of the design. The combination of certain features, due to interdependencies, may result in one cost while other features may produce a cost independent of the other features of the design. The effects of design features on the cost of a design changes due to whether features have interdependencies with other features or if the feature effects are independent of other design features. As an example, a design with feature A may cost \$X and a design with feature B may cost \$Y, however, a design with feature A and B may cost \$Z (\$Z ≠ \$X + \$Y). The set-up and run times for each instance (feature A, feature B, and features AB, for example) must be established.

REWORK COST

Rework cost is defined as the cost to rework repairable defects. Rework cost is determined in a fashion similar to theoretical cost. To determine rework cost, one must first determine the touch labor time required to initiate and complete the rework process; then apply the appropriate labor pay rate and factory overhead rate. The time required for the rework process is based on the number of defects that will be reworked/repaired.

Again, as with the theoretical touch labor time, the time for the rework process is separated into two components; the time to set-up for the rework process, and the run time needed to complete the rework process. In this case, the run time represents the processing time required to rework/repair (if feasible) one (1) defect that has been produced during the build process. To determine the total repair run time, the rework run time per defect is multiplied by the number of observed or estimated repairable defects per unit (DPU_{rework}) for that process step.

Therefore,

$$\text{Rework Cost (LO)} = (((\text{Rework Set-up Time} \times (1 - e^{-DPU_{rework}})) \div \text{Run Size}) + (\text{Rework Run Time} \times DPU_{rework})) \times (\text{Labor Rate} \times (1 + \text{Labor Overhead}))$$

As with the theoretical cost, the repair cost may also vary depending on the features of the design.

SCRAP COST

Scrap cost is defined as the cost to build additional units due to insufficient yield through a process.

The number of additional units that must be produced and the touch labor time required to produce them determines the scrap cost. It is assumed that the touch labor time for one additional unit equals the theoretical build time of producing one good unit.

To determine the number of additional units, the yield through the entire assembly process is determined. Since yield is the number of good units produced, the number of scrapped units (yield loss) are those units which were not successfully produced, or simply one minus the yield. Yield through the process is expressed as

$$e^{-DPU_{scrap}},$$

where DPU_{scrap} is the total defects per unit that have caused scrap. Defects that occur during a process that leave the unit of product unusable are scrap causing defects. Therefore,

$$\text{Scrap Cost (LO)} = \text{Theoretical Cost (LO)} \times \left[1 - \left(e^{-\sum_{i=1}^{n}(DPU_{scrap})}\right)\right];$$

where i is the i^{th} process step

Scrap cost at a given process step is allocated from the total scrap cost based on the cumulative yield up to and including that process step. Therefore,

$$\text{Cumulative Scrap Cost (LO)}_i = \text{Theoretical Cost (LO)}_i \times (1 - \text{Cumulative Scrap Yield}_i)\ ;$$

where i is the i^{th} process step

TOTAL COST

Total cost of the assembly is defined as the sum of the total theoretical cost, the total rework cost, and the total scrap cost. Consequently, total cost can be calculated as the sum of the costs for each process needed to produce the assembly. Therefore,

$$\text{Total Cost (LO)} = \text{Theoretical Cost (LO)} + \text{Rework Cost (LO)} + \text{Scrap Cost (LO)}$$

PROCESS OWNER DATA INPUTS

A team of process experts determine the design features that drive or influence the cost of a product manufactured by each process for a particular technology. Set-up and run labor times are determined for each feature characteristic. Additionally, Set-up and run labor times are determined for the repair of defects generated at a process step in the manufacturing flow. The process experts will also input the fraction of total predicted defects that are scrap causing defects or repairable defects. This information is generated from a number of sources such as historical data, work measurement studies, or educated engineering judgment. The process data is refined over time as more data is collected and analyzed by the process expert team.

The team of process experts determine the interdependencies between design features that drive different resulting labor times. In Figure 6, an example is given of the logic test for each feature characteristic selection and whether there are dependencies with any of the other feature characteristics. In each decision block, determination is made whether the feature characteristic effects the labor time. In the example, T4 is the assembly labor time for the process when the feature characteristics are not interdependent. The features in this case do not effect the time required for the process. Times T1, T2, and T3 represent labor time for features F1, F2, and F3, respectively, that have feature characteristics that are independent of each other. On the other hand, T8 represents the labor time for a process where each of the feature characteristics are interdependent.

Additionally, T8 may have a number of different labor times associated with it depending on which feature characteristics are selected. Table II is an example of the possible combinations of labor times that might be expected when a process has 3 interdependent features and each feature can be one of two possible characteristics. The combinations can result in 8 different labor times, depending on which design feature characteristics are selected.

Feature 1 AND	Feature 2 AND	Feature 3	equals (=)	Time (t)
Characteristic 1	Characteristic 1	Characteristic 1	=	t1
Characteristic 2	Characteristic 2	Characteristic 1	=	t2
Characteristic 1	Characteristic 2	Characteristic 1	=	t3
Characteristic 2	Characteristic 1	Characteristic 1	=	t4
Characteristic 1	Characteristic 1	Characteristic 2	=	t5
Characteristic 2	Characteristic 2	Characteristic 2	=	t6
Characteristic 1	Characteristic 2	Characteristic 2	=	t7
Characteristic 2	Characteristic 1	Characteristic 2	=	t8

TABLE II. TIMES RESULTING FROM FEATURE COMBINATIONS

The effects of interdependencies between design feature characteristics for a process may be different when considering repair labor time than from the effects on theoretical labor time. The team of process experts determine the type of defects that might be encountered, due to feature characteristics, and then determine the degree of difficulty to repair those type of defects, if repairable. The interdependencies are determined in the same manner as described earlier.

The labor times usually represent the time to manufacture a unit that is "fully learned", that is to say, that little additional improvement can be realized from building additional units past this predetermined unit basis. However, this n^{th} unit can be any unit number established by the process expert team. The learning or improvement curve is also determined for a particular technology by the team. A table of labor rates is provided to complete the cost calculations.

As the user makes feature selections in the quality model, the effects are displayed in terms of labor cost with applied overhead (graphical representation) and the percentage of the total cost that is non-value added (%NVA),

shown in the lower left corner of Fig. 3. Each selection will cause the calculation to update, showing their individual effect on both the process and the effect at the worksheet level. This will allow optimization at the process level.

User input at the worksheet level is minimal since most of the design description is accomplished in the quality model. The user has the ability to update the quantities or override model output if extenuating circumstances require such action.

Unusual design additions that are not handled by pre-established models can be added to the worksheet, as shown on row 18 in Fig. 7, and accounted for in the overall roll-up of cost, defects, and cycle time. Such inputs require judgment on the part of the user, through consultation with the process experts.

To complete the cost calculations, the manufacturing profile for each product being analyzed must be established, as shown in Fig. 8. The user must input the quantity of products, produced, whether this product had been manufactured previously to claim additional learning, the expected lot size, the production build schedule, and the labor rates desired calculations. Other header information is needed; such as, program name, user's name, analysis date, assembly name, part number and revision.

Fig. 4 shows the output of the quality model returned to the technology worksheet on row 11 in a summary level view. Other views of the technology worksheet can display detail regarding cost and labor hours, as shown in Figs. 9 and 10.

A flow block diagram of the cycle time predictor model is shown in Fig. 11. The user and process owner inputs to the model are shown on the left and the outputs are shown on the right. The inputs are DPMO, design quality, process opportunities, scrap rate, rework hours, build hours, learning curve - total units, delays and processing time. The new inputs added are delays and processing time. The model calculations that occur in each data transformation blocks 71-82 are numbered and can be found in the equations Table III.

71. Total Opportunities = Process Opportunities × Design Quantity

72. Total DPU = Total Opportunities × dpmo ÷ 1,000,000

73. Scrap DPU = Total DPU × Scrap Rate

74. Rework DPU = Total DPU - Scrap DPU

75. $\text{Yield}_{scrap} = e^{-DPU_{scrap}}$

76. Rework HPU = Rework Hours $\times DPU_{rework}$

77. Scrap HPU = Build Hours × $(1 - \text{Yield}_{scrap})$

78. Theoretical HPU = Build Hours × Design Quantity

79. Total HPU = Rework HPU + Scrap HPU + Theoretical HPU

80. HPU at TLMP = Total HPU × (Unit_{TLMP} /Unit Basis)^((LOG(Learning Curve))/LOG(2));

where Unit_{TLMP} =
(((Total Learned Units+0.5)^(1+(LN(Learning Curve)/LN(2))))
-(0.5^(1+(LN(Learning Curve)/LN(2)))))/((1+(LN(Learning Curve)
/LN(2)))*(Total Learned Units)))^(1/(LN(Learning Curve)/LN(2)))

81. Cycle Time at TLMP = HPU at TLMP + Processing Time + Delays

82. Percent NVA = ((Rework HPU + Scrap HPU + Theoretical HPU Set-up + Delays) / (Total HPU + Processing Time + Delays)) ×100

TABLE III. CYCLE TIME MODEL EQUATIONS

The "Processing time" is defined as time other than touch labor time associated with a particular process or event which is required to complete that particular process. This time would include such events as chemical process cure times, machine processing time (if it runs independent of an operator), oven bake, and the like. The assumption here is that the processing time is additive to the labor time associated with the process and is required as part of the entire process.

The processing time may vary depending on the features of the design. The effects of design features on the

processing time of a design changes due to whether features have interdependencies with other features or if the feature effects are independent.

The delays are defined as the time inherent to a particular process that require an item or unit being produced to set idle, without any processing adding to the value of the product. This time would include queue time while an item is at rest waiting for the next step in the process to occur. Again, delays vary depending on the features of the design.

A team of process experts determine the design features that drive or influence the processing time and delays of a product manufactured by each process for a particular technology. This information can be generated from a number of sources such as historical data, work measurement studies, or educated engineering judgment. The process data is refined over time as more data is collected and analyzed by the process expert team.

As with the cost model, the team of process experts determine the interdependencies between design features that may drive different resulting processing and delay times. The methodology that is used to determine theoretical labor times and repair times can be applied to determine the processing and delay times for a process.

As the user makes feature selections in the quality model, the effects are displayed in terms of total cycle time and the percentage of the total cycle time which is non-value added (% NVA), as shown previously in the lower left corner of Fig. 3. Each selection will cause the calculation to update, showing their individual effect on both the process and the effect at the worksheet level. This will allow optimization at the process level.

User input at the worksheet level is minimal since most of the design description accomplished in the quality model. The user has the ability to update the quantities or override model output if extenuating circumstances requires such action. Unusual design additions that are not handled by pre-established models can be added to the worksheet as discussed earlier for the cost model, and as shown previously on row 18 in Fig. 7.

The manufacturing profile for each product being analyzed must be established as discussed earlier for the cost model, and as shown previously in Fig. 8.

As discussed earlier in the cost model, Fig. 4 shows the output of the quality model returned to the technology worksheet on row 11 in a summary level view. Fig. 12 shows the technology worksheet view that displays the detail regarding cycle time.

To complete the technology worksheet, the user continues to describe the design in terms of the process steps required to manufacture the product. The user selects the appropriate process capability models that coincide with the process steps. Then, for each process capability model, the design is defined by selecting the feature characteristics. The process capability model output is returned, line by line, to the technology worksheet. Figure 13 shows an example of a completed worksheet. Each line of data on a completed worksheet represents the output from a process capability model.

Attribute models, variable models, and variable/attribute models can be used to predict the individual and cumulative manufacturing cost, quality, and cycle times. The applications supports other types of databases. In the embodiment to follow the database is Access and the following nomenclature, abbreviations and definitions are used.

Nomenclature /Abbreviations / Definitions

Cost	Cost of manufacturing or assembling parts including MLO.
Quality	The manufacturability of a design with regards to FTY loss during fabrication.
Cycle Time	The average number of days required during manufacturing from order placement to final delivery.
Sigma	A measurement of quality used to compare processes.
Dpmo	Defects per million opportunities
Dpo	Defects per opportunity
Opportunity	The opportunity in a design to create or incorporate a manufacturing defect.
MLO	Material, labor, and overhead
Recurring	Expenses that reoccur each time a new lot of product is machined.
Non-recurring	Expenses that only occur once regardless of the number of lots run, this would typically include expenses like hard tooling and N/C programming.

Part basis	The number of parts that the time per feature is based on i.e.. (200 parts).
Learning curve	The logarithmic curve that time and cost increase or decrease based on the part quantity, part basis, and percent learning curve assigned
Machinability factor	A factor used to adjust manufacturing time based on the Machinability of a given material type.
Learning curve	factor A factor used to adjust manufacturing time based on the learning curve and part quantity verses a part basis.
Material size	factor A factor used to adjust manufacturing time based on the size of a given part.
Characteristic factor	A factor associated with a characteristic of a process or feature which is used to adjust predication.
Percent scrap	The percent of predicted defects that will require scrapping the parts or assemblies by process.
Percent rework	The percent of predicted defects that will require rework by process.
Design feature	A physical requirement of a design which is the prominent part of a feature which adds additional design characteristic, or a specific process requirement called out on the design print. (i.e. surfaces, holes, paint, alodine, etc.)
Design characteristic	An individual requirement of a feature which adds additional detail to a feature or process. (i.e. surface tolerance type, paint color, etc.)
Attribute model	Models which predict cost, quality, or cycle time based on raw data which is expressed in percentages, ranges, and or go/no go terms.
Variable model	Models which predict cost, quality, or cycle time based on standard deviation, logarithmic curves or variable data.
Variable/attribute	model Models which predict cost, quality, or cycle time using both variables and attributes data.
Setup time basis	The average time of a setup per process without any judgments.
FTY loss	First time yield loss, or the percent of defects expected without any rework (e-dpu).
Rework time/feature	The amount of time to rework a part per feature based on process.
Previous process	times Manufacturing time accumulated prior to the current process.
Standard deviation	A statistical number used to describe process capability.

Referring to Fig. 14 there is illustrated a graphical representation of the user input flow required of this methodology. The first step 121 is selecting the primary technology.

Figure 15 shows an actual screen used to choose the primary technology used to manufacture the individual parts or assemblies. Upon start up of the software program, this screen will be presented for the user to make his or her choice of the primary technology associated with fabricated or assembled part being designed. Options include metal fabrication, plastic injection, casting, circuit card fabrication, TFN fabrication, Gallium Arsenic, cryogenic cooler fabrication, MA/FA assembly, microwave assembly, focal plane array assembly, optical assembly, circuit card assembly, hybrid assembly, and other assembly or fabrication technologies. Each button on the screen takes the user to the next lower level of information required to either describe the features, characteristics, and or processes required to predict the cost, quality, or cycle time of fabricating individual parts or assemblies by technology area. Future graphical displays in this application will be based on the assumption that the "Metal Fabrication Technology" button was pushed here and we will be working in its technology area.

Figure 16 shows the Part type menu which is the first menu displayed after pressing the "Metal Fabrication Tech-

nology" button on the "Primary Technology Screen 7. This is step 123 in Fig. 14. On this screen, the user inputs basic information such as material type, total part quantity, lot size, part size, part number and revision, who completed the analysis and the date. Hourly manufacturing rates, overhead charges, and other adders can be included or changed from this screen using the "Mfg. rate button. The analysis may be saved, recalled, (if completed earlier), new, printed, and viewed in a Pareto report on the screen before saving. The user views this screen initially to input data and again later after the analysis has been completed to see the overall cost of manufacturing the total quantity of parts required.

The user chooses the general part type from the pictures on the corresponding buttons. Options are machined part, cylindrical part, sheet metal part, process analysis, and manual inputs. The selection takes the user to step 125 in Fig. 14. The "process analysis" button is a manual override to directly choose process without regard to internal rules. The manual inputs" button is used for, direct cost, quality, and cycle time inputs. This corresponds to the inputs in the flow diagrams in Fig. 2, 5, and 11 above.

Figure 17 shows the Machined part surfaces screen which is shown after pressing the "Machined Part" access to all four primary features of a button on the "Part type menu" screen. This screen allows access to all four primary features of a machined part which includes surfaces, holes, finish processes, and assembly processes. This is step 127 in Fig. 14. Surfaces are separated by two types, prismatic and complex.

Under each of the primary features are the describing characteristics of each. The user describes the machined part by it's features and characteristics located on these screens. Both variable and attribute models are used simultaneously for prediction cost, quality, cycle time, and performance. This machined part surfaces screen requires the user to use drop down box choices on the Tolerance type and manually input the quantity, sq./in, and tolerance. Variable models are primarily used for these predictions and N/C machining centers or N/C jig bores are generally the processes chosen for machining the surfaces. All of the other fields are calculated based on the variables models which are embedded in the Toolset so that we can view the individual and cumulative cost, quality, and cycle time contributions of the design.

Figure 18 shows the Machined part holes screen which is shown after pressing the "Holes" tab from the Machined part surfaces screen. This screen allows access to all four primary features of a machined part which includes surfaces, holes, finish processes, and assembly processes. This is step 129 in Fig. 14. The user describes the machined part by it's features and characteristics located on these screens. This machined part hole screen requires the user to use drop down box choices on the tolerance type, dimension, and various other fields -with manual input the quantity, and tolerance. Variables models are primarily used in this model for predictions. All of the other fields calculated are based on variables models and generally choose the process of N/C centers or N/C jig bores for boring, milling, reaming or drilling the holes. Both individual and cumulative cost, quality, and cycle time are displayed on the screen or in the grid when features and characteristics are describing the design.

Figure 19 shows the Alodine finish process screen which is the initial screen shown after pressing the "Finishes" tab from any of the primary feature screens. This model is primarily an attribute model. The user chooses various characteristics about the process located on the screen which effect the cost, quality, and cycle time of the alodine process. This process is determined by the design when called out in the notes or processes section. The cost, quality, and cycle time indicated in the right hand boxes are only for the alodine process.

The process of alodine starts with a base cost, base quality, and base cycle time. Then they each either increase or decrease by certain percentages based on characteristic factors attached to each of the characteristics describing the process. Some characteristics effect all three metrics, some do not.

Alodine is a chemical process (chromate conversion) used primarily for corrosion resistance on aluminum parts which result in very little build up and generally a faint yellowish tint.

Figure 20 shows the Anodize finish process screen which is located under the "Finishes" tab from any of the primary feature screens. This model is primarily an attribute model. The user chooses various characteristics about the process located on the man which effect the cost, quality, and cycle time of the anodize process. This process is determined by the design when called out in the notes or processes section. The cost, quality, and cycle time indicated in the right hand boxes are only for the anodize process.

The process of anodize starts with a base cost, base quality, and base cycle time. Then they each either increase or decrease by certain percentages based on characteristic factors attached to each of the characteristics describing the process.

Anodize is a chemical process used, primarily for wear and corrosion resistance on aluminum parts which generally results in a slight material build up with various colors options.

Figure 21 shows the Passivate finish process screen which is located under the "Finishes" tab from any of the primary feature screens. This model is primarily an attribute model. The user chooses various characteristics about the process located on the screen which effect the cost, quality, and cycle time of the anodize process. This process is determined by the design when called out in the notes or processes section. The cost, quality, and cycle time indicated in the right hand boxes are only for the Passivate process.

The process of passivation starts with a base cost, base quality, and base cycle time. Then they each either increase or decrease by certain percentages based on characteristic factors attached to each of the characteristics

describing the process.

Passivation is a chemical process used primarily for corrosion resistance on stainless steel material type parts which generally results in a very slight material build up with a faint yellowish tint.

Figure 22 shows the Plating finish process screen which is located under the "Finishes" tab from any of the primary feature screens. This model is primarily an attribute model. The user chooses various characteristics about the process located on the screen which effect the cost, quality, and cycle time of the plating process. This process is determined by the design when called out in the notes or processes section. The cost, quality, and cycle time indicated in the right hand boxes are only for the plating process.

The process of plating starts with a base cost, base quality, and base cycle time. Then they each either increase or decrease by certain percentages based on characteristic factors attached to each of the characteristics describing the process.

Plating is a chemical or electrochemical process used on various materials to effect the performance of the base material such as corrosion resistance, wear resistance, conductive resistance, aesthetics, and other possibilities.

Figure 23 shows the Painting finish process screen which is located under the "Finishes" tab from any of the Primary feature screens. This model is primarily an attribute model. The user chooses various characteristics about the process located on the screen which effect the cost, quality, and cycle time of the painting process. This process is determined by the design when called out in the notes or processes section.

The process of painting starts with a base cost, base quality, and base cycle time. Then they each either increase or decrease by certain percentages based on characteristic factors attached to each of the characteristics describing the process.

Painting is a process used on various materials to effect aesthetics, corrosion resistance, wear resistance, etc. which usually results in various colors, textures, or finishes.

Figure 24 shows the mask/demask process screen which is located under the "Finishes" tab from any of the primary feature screens. This model is primarily an attribute model. The user chooses various characteristics about the process located on the screen which effect the cost, quality, and cycle time of the painting process. This process is determined by the design when called out in the notes or processes section.

The process of mask/demask starts with a base cost, base quality, and base cycle time. Then they each either increase or decrease by certain percentages based on characteristic factors attached to each of the characteristics describing the process.

Mask/demask is a process used to keep paint and chemicals free from certain areas of the parts to effect aesthetics, corrosion resistance, wear resistance, etc.

Figure 25 shows the marking finish process screen which is located under the "Finishes" tab from any of the primary feature screens. This model is primarily an attribute model. The user chooses various characteristics about the process located on the screen which effect the cost, quality, and cycle time of the painting process. This process is determined by the design when called out in the notes or processes section.

The process of marking starts with a base cost, base quality, and base cycle time. Then they each either increase or decrease by certain percentages based on characteristic factors attached to each of the characteristics describing the process.

Marking is a process used to identify parts or assemblies as well as functional use requirements such as switch indications, degree markings etc.

Figure 26 shows the heat treat finish process screen which is located under the "Finishes" tab from any of the primary feature screens. This model is primarily an attribute model. The user chooses various characteristics about the process located on the screen which effect the cost, quality, and cycle time of the painting process. This process is determined by the design when called out in the notes or processes section.

The process of heat treating starts with a base cost, base quality, and base cycle time. Then they each either increase or decrease by certain percentages based on characteristic factors attached to each of the characteristics describing the process.

Heat treating is a process used to change the material characteristics of metal. These include hardening, softening, annealing and other desired physical characteristics of the Material after the process. Heat treating can occur prior to, during, or after all processes with different results depending upon the timing.

Figure 27 shows the Cylindrical part surface screen which is shown after pressing the "Cylindrical Part surfaces' button located on the "Part type menu" screen. This screen allows access to all three primary features of a cylindrical part which includes cylindrical part features, finish processes, and assembly processes. In some instances a user may choose to describe the features and characteristics of a part using both the 'Cylindrical part surfaces" screen and the machined part surfaces/holes screen. Part features that are described using the "Cylindrical part surfaces" screen will use the primary process of a CNC lathe for turning ID's, OD's, lengths, etc.

The "Cylindrical part surfaces" screen requires the user to use drop down box choices on characteristics such as dimension type, tolerance type, + tol., - tol., and quantity. All of the other fields are calculated using the embedded variables models so we can view the cost, quality, and cycle time contributors both individually and cumulatively.

Figure 28 shows the "Sheet metal features' screen which is shown after pressing the "Sheet metal parts" button located on the "Part type menu" screen. This screen allows access to all three primary features of a sheet metal part which includes sheet metal features, finish processes, and assembly processes. In some instances a user may choose to describe the features and characteristics of a part using both the "Sheet metal features" screen and the "Machined part surfaces/holes" screen. Part features that are described using the "Sheet metal features" screen will use the primary process of a CNC punch press machine of break press.

The "Sheet metal features" screen requires the user to use drop down box choices on characteristics such as dimension type, tolerance type, tolerance and quantity. All of the other fields are calculated using the embedded variables models so we can view the cost, quality, and cycle time contributors both individually and cumulatively.

Figure 29 shows the "Assemblies" screen after pressing the "Assemblies" tab once you have navigated down in the part type. This model is primarily an attribute model and only includes the assembly type Process which occur in the Metal Fabrication Technology area. Other assembly processes are located in the major technology area of which they occur.

The user chooses the features to be assembled and their quantity per assembly from this screen. The model includes the cost of the parts being assembled, the labor cost of assembling them, and any rework costs associated with the quality.

Figure 30 shows the "Manual cost, quality, cycle time input" screen after pressing the "Manual input" button located on the "Part type menu" screen. This screen is used for direct inputs of cost, quality, and cycle time and is not effected by any formula other than a straight roll up of the data.

The intent of this screen is to be a place where data can be input because no other screen includes this data, or you have actual data on the individual part and prefer it verses a predicted number. Also all possible processes can not be included in any one Toolset and this allows for that possibility with maximum flexibility.

The formulas used for the embodiment of Figs. 14-30 are as follows:

Learning curve factor	(((1/learning curve basis qty.]^ (Log([% learning curve])/Log(2)))))*([total quantity required])^ (Log([% learning curve])/Log(2))
Size Factor	(((1/([maximum cu/in]^ (Log([size curve])

	/Log(2))))) * ([size basis])^ (Log([size curve]) /Log(2)))
Machinability factor	(if[material type]= 1, then machinability type 1; if = 2, then machinability type 2; if = 3, then machinability factor = machinability type 3, etc.)
Sigma to Dpmo conversion	((((((1+.049867346*sigma)+0.0211410061*sigma 2) +0.00322776263*sigma^3)+0.0000380036*sigma ^ 4) +0.0000488906 *sigma ^ 5)+0.000005383*sigma^6)-16/2)* 1000000
Dpo to sigma conversion	(Log(1/dpo^2)^0.5)-(2.515517+0.802853*(Log(1/dpo^2)^0.5+0.010328*(Log(1/dpo^2)^0.5^2)/(1+1.432788*(Log(1/dpo^2)^0.5+0.189269*(Log(1/dpo^2)^0.5)^+0.001308*(Log(1/dp0^2)^0.5^3)+1.5
Dpu	Defects per opportunity (DPO)x opportunity count
Dpo	Defects per million opportunities/1,000,000
Dpo	Dpu/opportunity
Sigma	Tolerance/standard deviation
First time yield (fty)	e^-dpu
Total dpu	Total opportunities x total dpo
Variables data cost formula	[Qty[(base time + rework time + scrap time + setup avg time)($/hr*(overhead rate* 1+ % adders)) (learning curve factor* machinability factor*size factor)]] + ((material cost+scrap material cost)(1+material overhead %))
Attribute data cost formula	[Qty[(base time + rework time + scrap time + setup avg time)($/hr*(overhead rate*(1+ % adders)))(attribute characteristics cost factors)]]+((material cost+scrap material cost)* (1+material overhead %))
Process type formula	Process = technology type + part type + features + characteristics
Rework time formula	[(Qty * rework time base)(total % yield loss * % rework)]

In the embodiment to follow, the database used is a SQL server with a Visual Basic Interface. The following nomenclature, abbreviations, and definitions are used.

Build Run Time	Average labor time required to manufacture one unit of production
Build Setup Time	Average labor time required to prepare for the manufacture of one lot of product
Build Unattended Time	Manufacturing process time that does not include run time, i.e. other than operator attended processing time.
Default	The initial value of a characteristic when a new worksheet evaluation is performed.

Characteristic Value	Value must be equal to or within the upper and lower limits of the characteristic. Value must be greater than or equal to zero and less than ten thousand. This value is input on the CHARACTERISTIC window for "Rated User Input" and "User Input" features.
dpmo	Defects per million opportunities
dpmo Rate	Value from zero to one which is assigned to a rated feature characteristic. The value determines how much contribution the feature characteristic contributes to the overall quality score. The value is input on the CHARACTERISTICS window.
DPU	Defects per unit
Rework Run Time	Average labor time required to rework/repair one defect during manufacture of product.
Rework Setup Time	Average labor time required to prepare for the rework/repair process
Rework Unattended Time	Unattended run time associated with rework/repair activity
Standard Deviation	Statistical index of variability which describes the manufacturing capability of a process
Tolerance	The permissible deviation from a specified value of a design specification
Unattended hours/time	The build or rework manufacturing process time where no labor is being charged. Unattended hours is a component of cycle time.
Values for Rated User Input Feature	When adding a rated user input feature, you need to input values for upper limit, rated upper limit, upper limit rate, lower limit, rated lower limit, and lower limit rate. These values are defined using the graph on Fig. 31. The y-axis represents values for the rate and the x-axis for input values. From the input values 0 to 10, the rate is 0. At the input value of 10, the rate increases to 0.4. From input values 10 to 20, the rate increases to a value of 0.6 at the input value of 20, the rate increases to 1. All input values from 20 to 30 have a rate of 1. The lower limit in this example is 0. The upper limit in this example 30. The rated lower limit is 10, and the rated upper limit is 20. The lower limit rate is 0.4 and the upper limit rate is 0.6.
Weight	A value assigned to a rated feature ranging from greater than 0 to 1. Sum of all weights is 1.
Zvalue	Standard Normal Deviate; a statistical value based on the process standard deviation used to calculate DPO.

To build a model, there are 7 main tasks to be completed: add technology, add labor and overhead rates, add model, add features and feature characteristics, add restrictions, add dependencies, and add formulas. A technology is a manufacturing process category containing one or more process capability models (PCM). Examples of technologies are Circuit Card Assembly, PWB Fab, Metal Fab, Interconnect, Electrical Assembly, and Mechanical Assembly. A model, or process capability model (PCM), is a mechanism for predicting quality, cycle time, and cost metrics for one or more manufacturing processes. The model is defined with features, feature characteristics, restriction, dependencies, and formulas. A feature is a descriptor of a part design or component of a part design that further defines a Process Capability Model. Also a description of a manufacturing process. Feature characteristics further define the feature. Each feature characteristic has associated with it a unit of measure and value.

There are six different types of features. These features are distinguished by the actions and calculations required on a worksheet:

1. Rated Feature - A weight is associated with each feature. Each characteristic of this feature has a rate. On the worksheet, only one characteristic can be selected for this feature. You may use this type of feature if you want the system to use the "dpmo range and feature scores" method for quality calculations.
2. Non-rated Feature - This feature can be used in assigning dependent values. Your would not use this feature if you want to use the "dpmo range and feature scores" method of calculating quality. No values are required to be input at the time of adding the feature and a characteristic to the feature.
3. Rated User Input Feature - This feature has a weight associated with it. You can only add one characteristic to this feature. The characteristic to this feature has limits and a characteristic default value associated with it. On the worksheet, the characteristic default value displays as the input value, or the user can input a different value. You may use this type of feature if you want the system to use the "dpmo range and feature scores" method for quality calculations.
4. User Input Feature - This feature can have a characteristic with limits and a default value. On the worksheet, the default value displays as the input value, or the user can input a different value. The system allows only one char-

acteristic to be assigned to a user input feature. This feature is not rated.

5. Multiple Selection Feature - This feature allows more than one characteristic selection on the worksheet. For this feature, the characteristics are defined as either being "on" or "off". A characteristic that is "on" is automatically selected on the worksheet. This feature is useful; when determining the answers to questions that help to define a value for a user-defined calculation.

6. Process Feature - This feature is used to help determine the process to be used as related to the model. The characteristic of the feature would be suggested processes. On the worksheet, characteristics for process features are not shown. After a model is evaluated, the select characteristics for the process feature is displayed. This is the recommended process.

The Table IV below shows the required input values for each feature and its characteristics:

Table IV

Type	Values Required
Rated Feature	Weight, dpmo rate.
Non-Rated Feature	No Values required.
Rated User Input Feature	Weight, upper limit, rated upper limit, upper limit rate, lower limit, rated lower limit, lower limit rate, default characteristic value.
User Input Feature	Upper limit, lower limit, default characteristic value.
Multiple Selection Feature	Default characteristic value.
Process Feature	No values required.

DPU is calculated by one of three methods: the defects per million opportunities (dpmo) range and feature scores method, the mean dpmo and feature factors method, and the standard deviation and Zvalue method.

The dpmo range and feature scores method starts with a dpmo range, calculates a predicted dpmo by applying a total score factor which is based on individual design feature scores, which are based on feature weights and feature characteristic rates. The predicted dpmo is then converted to a predicted DPU.

In order to use this method, you need to:

- Add at least one rated or rated user input feature
- Input values for dpmo upper and lower limits on the MODEL SETUP window
- Create a user-defined formula for Total Opportunities

The mean dpmo and feature factors methods starts with a mean dpmo, converts it to a mean DPU, and then calculates a predicted DPU by applying a total DPU factor which is based on individual design feature DPU factors. The predicted DPU is then converted to a predicted dpmo.

In order to use this method, you need to:

- Input a value for dpmo on the MODEL SETUP window
- Add feature and/or model dependencies for DPU Factor
- Create user-defined formulas for Total Opportunities and Total DPU Factor

The standard deviation and Zvalue method starts with a process standard deviation and design tolerances and calculates a Zvalue, then determines a Defects Per Opportunity (DPO) based on the Zvalue. The DPO is then converted to a predicted DPU.

In order to use this method, you need to:

- Leave values for dpmo mean, dpmo upper limit, and dpmo lower limit blank on the MODEL SETUP window.
- Add model dependencies for Standard Deviation.

Create user-defined formulas for Total Opportunities and Tolerance.

See Table V for formulas to calculate DPU.

The system-defined formulas for cost and cycle time are present in Table VI. In order to have cost and cycle time

calculated correctly, you need to:

- Add labor rates and overhead
- Create user-defined formulas for:

  Build Run Time
  Build Setup Time
  Build Unattended Time
  Rework Run Time
  Rework Setup Time
  Rework Unattended Time

A restriction is a condition that is set among two features, called primary and secondary features. The condition is added with a comment or message. This message displays during a model evaluation session when the user selects the combination of feature characteristics that are "restricted".

The purpose of the restriction is to discourage the user from selecting restricted combinations of feature characteristics. An informational message is displayed to the user after the restricted combination has been selected. The user is able to proceed with the selection, but it is not recommended.

The number of restrictions is limited by the number of combinations of two feature characteristics. The combinations of feature characteristics have to be for different features within the same model.

- A dependency is a value assigned to one or more of the following variables that will be based on feature characteristic selections made by the end user during a model evaluation.

  - Build Run Hours
  - Build Setup Hours
  - Build Unattended Hours
  - DPU Factor
  - Opportunity Factor
  - Rework Run Hours
  - Rework Setup Hours
  - Rework Unattended Hours
  - Standard Deviation

The model builder defines the dependent values based on one feature/feature characteristic combination or multiple feature/feature characteristics combinations for a model.

Dependencies can be defined at the model and/or feature level. Feature level dependencies define values for a feature, and are dependent upon other feature/characteristic values. Model level dependencies define values for a model, and are dependent on the relationship between feature/characteristics.

The value for Standard Deviation can only be defined at the model level.

Within the system there are user-defined formulas and system-coded formulas. The system-coded formulas are functions of the user-defined formulas. The user defined formulas can be created using a CREATE FORMULAS window generated and associated program.

User defined formulas are formulas that are defined by the user. For DPU metrics, the user must define the formulas for Tolerance, Total Opportunities, and Total DPU Factor, depending on the method for calculating quality metrics. Total Opportunities must be defined for all methods. For Cycle Time and Cost metrics, the user must define the formulas for Build Run Time, Build Setup Time, Build Unattended Time, Rework Run Time, Rework Setup Time, Rework Unattended Time.

To add a technology field name and comment field are generated and filed out. They are:

Field Name	Comment
Learning curve percent	This value is used in cost and cycle time calculations.
Learning curve basis	This is used in cost and cycle time calculations.
Process Own r	Input the manager responsible for the technology.

Optionally, the fields:

Field name	Comment
Cycle Time Adjustment	This is used in cost and cycle time calculations. If this value is left blank, the value defaults to 1.
Comments	These comments only display on-line. Input any comment that should be viewed regarding the technology.

To add labor and overhead rates, in put the following fields

:Field Name	Comment
Year	You can input values by calendar year for ten years. The system sorts the years in chronological order. The year should be in the format YYYY, e.g. 1996).
Labor Rate	
Overhead Percent	

To add a model the following fields are step up and filed out.

Field Name	Comment
Revision	Defaults to blank. This field accepts alphanumeric characters.
DPMO Upper Limit	These values are used in the DPU calculation using the dpmo range and features scores method.
DPMO Lower Limit	
DPMO Mean	This value is used in the DPU calculation using the mean dpmo and feature factors method.
Scrap Rate	Defaults to 0. Used in the dpmo range and feature scores method.
Opportunity Count	Defaults to 1. Can be used to calculate total opportunities.
Number of Times Model is Applied	Defaults to 1. Used in DPU, cost, and cycle time calculations. This value displays on the PCM EVALUATIONS windows.
Comments	

The model is added to the listing of technologies.

To add a feature to a model the system generates a feature field by a "Features" window and user inputs the name of the feature. The feature is classed as a type. For a rated type input name in "Characteristic" field and input value in dpmo Rate field. The value must be greater than or equal to zero and less than or equal to one. For a Rated user Input type input name in "Characteristic" field and input values for Upper Limit, Rated Upper Limit, Upper Limit Rate, Lower Limit, Rated Lower Limit, Lower Limit Rate, and Default Characteristic Value. For a Process feature type input name in "Characteristics" field. For a non-rated feature input name in "Characteristics" field. For a User-input feature, input name in "Characteristics" field and input values for Upper Limit, Lower Limit, and Default. For a Multi-Select feature, input name in "Characteristics" field and select a default.

To add formulas a CREATE FORMULAS program with associated windows is created to add equations or change equations in the transition blocks.

The following terms are used in building worksheets.

Constant Year $	Baseline year for cost of money calculations
Prior Units Built	Quantity of units prior to manufacture of contract build quantity for which learning experience can be claimed (if no significant breaks in production have occurred).
Lot Size	Number of units released for manufacture at one time.
Contract Build	Quantity Number of deliverable units specified in the contract.
Quantity Program	Manufacturing/design effort or individual project.

Learning Curve %	The rate of predicted improvement in cost due or cycle time due to manufacturing experience based on repetitiveness.
Learning Curve Basis	A point on the learning curve, represented by a unit value, from which all labor hour based estimates are derived.
Labor Rate	negotiated/approved hourly pay for fabrication or assembly labor.
Overhead %	Negotiated/approved overhead cost, represented as a percent of labor cost.

The Worksheet Setup screen is where the user begins to build a worksheet. The first step in building a worksheet is worksheet setup of definition. This can be done by scratch or by modifying a copy of an existing worksheet. Starting from scratch involves naming the worksheet and then defining some program level information that will be used in metric calculations and then determining from which technology the worksheet will be based (i.e. from which technology the models for the worksheet will be selected when assembling the worksheet). Modifying a copy of an existing worksheet involves using the worksheet copy function to copy an existing worksheet to a newly defined worksheet having a different program and worksheet name, and then modifying it. Modifications may include a change in Technology and/or program level information.

Once the worksheet is defined, it can be assembled or built using a setup screen. Building a worksheet involves selecting the unevaluated PCMs or models from a list of models previously created under the technology selected during worksheet setup. Once the models have been selected, they can be rearranged in an order in which they will appear in the body of the worksheet. The unevaluated worksheet has been built and is ready for evaluation. At this point, the user can evaluate the worksheet or save the unevaluated worksheet as a worksheet template that can be used as a starting point for future worksheets that need to be built using the same technology.

To build a worksheet, a worksheet program and worksheet screen is generated and is brought up from a menu bar. The worksheet program screen takes you to the Worksheet Set Up screen and program that has been generated. The setup screen has a Program field for entering the name of a program. In the Worksheet field, add the name of the worksheet. Input the following fields:

Field Name	Comment
Part Desc	Name of part.
Analysis By	Your Name.
Analysis Date	Today's date.
Constant Year $	Baseline year for $ value.
Prior Units Built	No. of units built to date.
Lot Size	No. of units in a lot.
Contract Build Qty.	No. of deliverable units specified in the contract.

Technology	The manufacturing technology category.
Material Type	The material type: Aluminum, steel, etc.
Material Size	Length, width, and height or length and diameter.
Program	The name of the program being evaluated.
Worksheet	The part number of the part or assembly being evaluated.

Each model can be evaluated. The user will make feature characteristic selections and/or inputs for each feature displayed, and then also calculate process. At this time, the quality, cost and cycle time metrics will be calculated, using a combination of user defined and system coded formulas. The model and worksheet summary metrics will be displayed on both of the model evaluation screens or printed on a printer. The format of the model and worksheet summary

metrics will be determined by the user and can be defined prior to or after metric calculation.

Once the model evaluation is complete, the user will go back to the worksheet screen where the model metric data will have been transferred to the worksheet as a line item, located under the unevaluated model description. If more than one model evaluation session has been completed prior to returning to the worksheet, each completed model evaluation will be represented as a line item on the worksheet, again located under the unevaluated model description in the order in which the evaluation sessions were completed.

TABLE V

Dpmo Range and Feature Scores Method

$$dpmo_{pred} = [(1 - \Sigma Scores)(DPMO\ Upper\ Limit - DPMO\ Lower\ Limit) + DPMO\ Lower\ Limit]$$

$$Scores = Rate * Weight$$

$$DPU_{pred} = (Total\ Opportunities * DPMO_{pred}) / 1,000,000$$

DPU_{scrap} = DPU_{pred} * Scrap rate

DPU_{rework} = DPU_{pred}-DPU_{scrap}

$Yield_{pred}$ = $e^{-DPUpred}$ * 100

$Sigma_{pred}$ = [(SQRT(LN(1 / ($dpmo_{pred}$ / 1000000)^2)))-(2.515517 + 0.802853 * (SQRT(LN(1 / ($dpmo_{pred}$ / 1000000)^2))) + 0.010328 * (SQRT(LN(1 / ($dpmo_{pred}$ / 1000000)^2)))^2) / (1 + 1.432788 * (SQRT(LN(1 / ($dpmo_{pred}$ / 1000000)^2))) + 0.189269 * (SQRT(LN(1 / ($dpmo_{pred}$ / 1000000)^2)))^2 + 0.001308 * (SQRT(LN(1 / ($dpmo_{pred}$ / 1000000)^2)))^3)] + 1.5

Mean Dpmo and Feature Factors Method

DPU_{avg} = (Total Opportunities * DPMO Mean) / 1,000,000

K_{dpu} = Product and/or sum of Non-Rated Feature Characteristic DPMO Factors (K_{factor})

= $K_{factor1}$ * $K_{factor2}$ + $K_{factor3}$ ... $K_{factorn}$

DPU_{pred} = K_{dpu} * DPU_{avg}

$dpmo_{pred}$ = DPU_{pred} * 1,000,000 / Total Opportunities

$Yield_{pred}$ = $e^{-DPUpred}$ * 100

$Sigma_{pred}$ = [(SQRT(LN(1 / ($dpmo_{pred}$ / 1000000)^2)))-(2.515517 + 0.802853 * (SQRT(LN(1 / ($dpmo_{pred}$ / 1000000)^2))) + 0.010328 * (SQRT(LN(1 /

(dpmo$_{pred}$ / 1000000)^2)))^2) / (1 + 1.432788 * (SQRT(LN(1 / (dpmo$_{pred}$ / 1000000)^2))) + 0.189269 * (SQRT(LN(1 / (dpmo$_{pred}$ / 1000000)^2)))^2 + 0.001308 * (SQRT(LN(1 / (dpmo$_{pred}$ / 1000000)^2)))^3)] + 1.5

Standard Deviation & Zvalue Method

Zvalue = Tolerance / Standard Deviation

DPO = [(((((((1 + .049867346 * (Zvalue - 1.5)) + .0211410061 * (Zvalue - 1.5)^2) + .0032776263 * (Zvalue - 1.5)^3) + .0000380036 * (Zvalue - 1.5)^4) + .0000488906 * (Zvalue - 1.5)^5) + .000005383 * (Zvalue - 1.5)^6)$^{-16}$) / 2]

DPU$_{pred}$ = DPO * Total Opportunities

dpmo$_{pred}$ = DPU$_{pred}$ * 1,000,000 / Total Opportunities

Yield$_{pred}$ = $e^{-DPUpred}$ * 100

Sigma$_{pred}$ = [(SQRT(LN(1 / (dpmo$_{pred}$ / 1000000)^2)))-(2.515517 + 0.802853 * (SQRT(LN(1 / (dpmo$_{pred}$ / 1000000)^2))) + 0.010328 * (SQRT(LN(1 / (dpmo$_{pred}$ / 1000000)^2)))^2) / (1 + 1.432788 * (SQRT(LN(1 / (dpmo$_{pred}$ / 1000000)^2))) + 0.189269 * (SQRT(LN(1 / (dpmo$_{pred}$ / 1000000)^2)))^2 + 0.001308 * (SQRT(LN(1 / (dpmo$_{pred}$ / 1000000)^2)))^3)] + 1.5

TABLE VI

CYCLE TIME FORMULAS

$\text{Yield loss}_{scrap} = 1 - e^{-DPUscrap}$

$\text{Yield loss}_{rework} = 1 - e^{-DPUrework}$

$HPU_{set\text{-}up}$ = Build Setup Time ÷ Lot Size

$HPU_{theoretical}$ = ($HPU_{set\text{-}up}$ + (Build Run Time * Number of Times Model is Applied))

HPU_{scrap} = $HPU_{theoretical}$ * Yield loss_{scrap}

HPU_{rework} = ((Rework Setup Time * Yield loss_{rework}) ÷ Lot Size) + (Rework Run Time * DPU_{rework})

HPU_{total} = $HPU_{theoretical}$ + HPU_{scrap} + HPU_{rework}

Total Learned Units = Prior Units Built + Contract Build Quantity

$Unit_{TLMP}$ = ((((Total Learned Units+0.5)^(1+(LN(Learning Curve)/LN(2)))) -(0.5^(1+(LN(Learning Curve)/LN(2))))))/((1+(LN(Learning Curve) /LN(2)))*(Total Learned Units)))^(1/(LN(Learning Curve)/LN(2)))

HPU_{TLMP} = HPU_{total} * ($Unit_{TLMP}$/Unit Basis)^((LOG(Learning Curve))/LOG(2))

HPU_{NVA} = $HPU_{set\text{-}up}$ + HPU_{scrap} + HPU_{rework}

$HPU_{\%\ NVA}$ = (HPU_{NVA} / HPU_{total}) *100

$$\text{Unattended Run Time}_{scrap} = \text{Build Unattended Time} * \text{Yield loss}_{scrap}$$

$$\text{Unattended Run Time}_{rework} = \text{Rework Unattended Time} * \text{Yield loss}_{rework}$$

$$\text{Cycle Time Per Lot}_{theoretical} = (\text{HPU}_{theoretical} * \text{Lot Size}) + \text{Build Unattended Time}$$

$$\text{Cycle Time Per Lot}_{scrap} = ((\text{HPU}_{scrap} * \text{Lot Size}) + \text{Unattended Run Time}_{scrap}) * \text{Cycle Time Adjustment}$$

$$\text{Cycle Time Per Lot}_{rework} = ((\text{HPU}_{rework} * \text{Lot Size}) + \text{Unattended Run Time}_{rework}) * \text{Cycle Time Adjustment}$$

$$\text{Cycle TimePer Lot}_{total} = (\text{Cycle Time Per Lot}_{theoretical} * \text{Cycle Time Adjustment}) + \text{Cycle Time Per Lot}_{scrap} + \text{Cycle Time Per Lot}_{rework}$$

$$\text{Cycle Time Per Lot}_{TLMP} = [(\text{HPU}_{TLMP} * \text{Lot Size}) + \text{Unattended Run Time}_{scrap} + \text{Unattended Run Time}_{rework} + \text{Build Unattended Time}] * \text{Cycle Time Adjustment}$$

$$\text{Cycle Time Per Lot}_{NVA} = ((\text{HPU}_{NVA} * \text{Lot Size}) + \text{Unattended Run Time}_{scrap} + \text{Unattended Run Time}_{rework}) * \text{Cycle Time Adjustment}$$

$$\text{Cycle Time Per Lot}_{\%\ NVA} = (\text{Cycle Time Per Lot}_{NVA} / \text{Cycle Time Per Lot}_{total}) *100$$

COST FORMULAS

$$Cost_{scrap} = HPU_{scrap} * (Labor\ Rate * (1 + Labor\ Overhead))$$

$$Cost_{rework} = HPU_{rework} * (Labor\ Rate * (1 + Labor\ Overhead))$$

$$Cost_{theoretical} = HPU_{theoretical} * (Labor\ Rate * (1 + Labor\ Overhead))$$

$$Cost_{total} = Cost_{rework} + Cost_{scrap} + Cost_{theoretical}$$

or

$$Cost_{total} = HPU_{total} * (Labor\ Rate * (1 + Labor\ Overhead))$$

$$Cost_{TLMP} = HPU_{TLMP} * (Labor\ Rate * (1 + Labor\ Overhead))$$

$$Cost_{NVA} = Cost_{rework} + Cost_{scrap}$$

$$Cost_{\%\ NVA} = ((Cost_{rework} + Cost_{scrap}) / Cost_{total}) *100$$

Although the present invention and its advantages have been described in detail, it should be understood that various changes, substitutions and alterations can be made herein without departing from the spirit and scope of the invention.

Claims

1. A capability predictor comprising:

   a database of capability data of multiple design characteristics;
   an interactive input means for selecting characteristics;
   a processor responsive to said selected characteristics for generating signals representing capability predictions according to predetermined algorithm; and
   a display responsive to said signals for displaying said predictions.

2. The predictor of Claim 1 wherein said design characteristics are process characteristics and said interactive means selects process design characteristics.

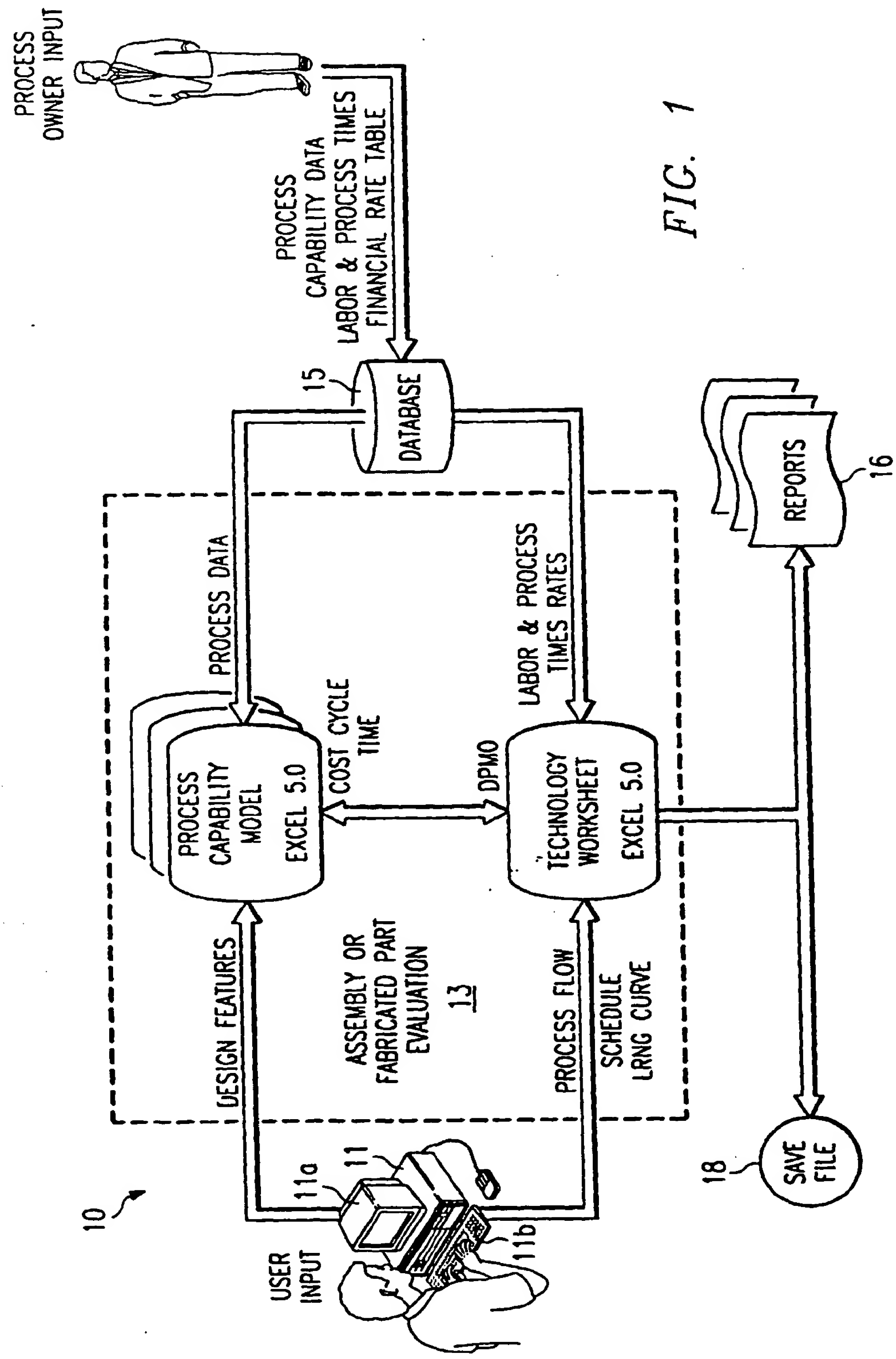

PROCESS
OWNER INPUT
PROCESS
CAPABILITY DATA
LABOR & PROCESS TIMES
FINANCIAL RATE TABLE
15
DATABASE
REPORTS
16
PROCESS DATA
LABOR & PROCESS
TIMES RATES
PROCESS
CAPABILITY
MODEL
EXCEL 5.0
COST CYCLE
TIME
DPMO
TECHNOLOGY
WORKSHEET
EXCEL 5.0
DESIGN FEATURES
ASSEMBLY OR
FABRICATED PART
EVALUATION
13
PROCESS FLOW
SCHEDULE
LRNG CURVE
10
USER
INPUT
11a
11
11b
18
SAVE
FILE

FIG. 1

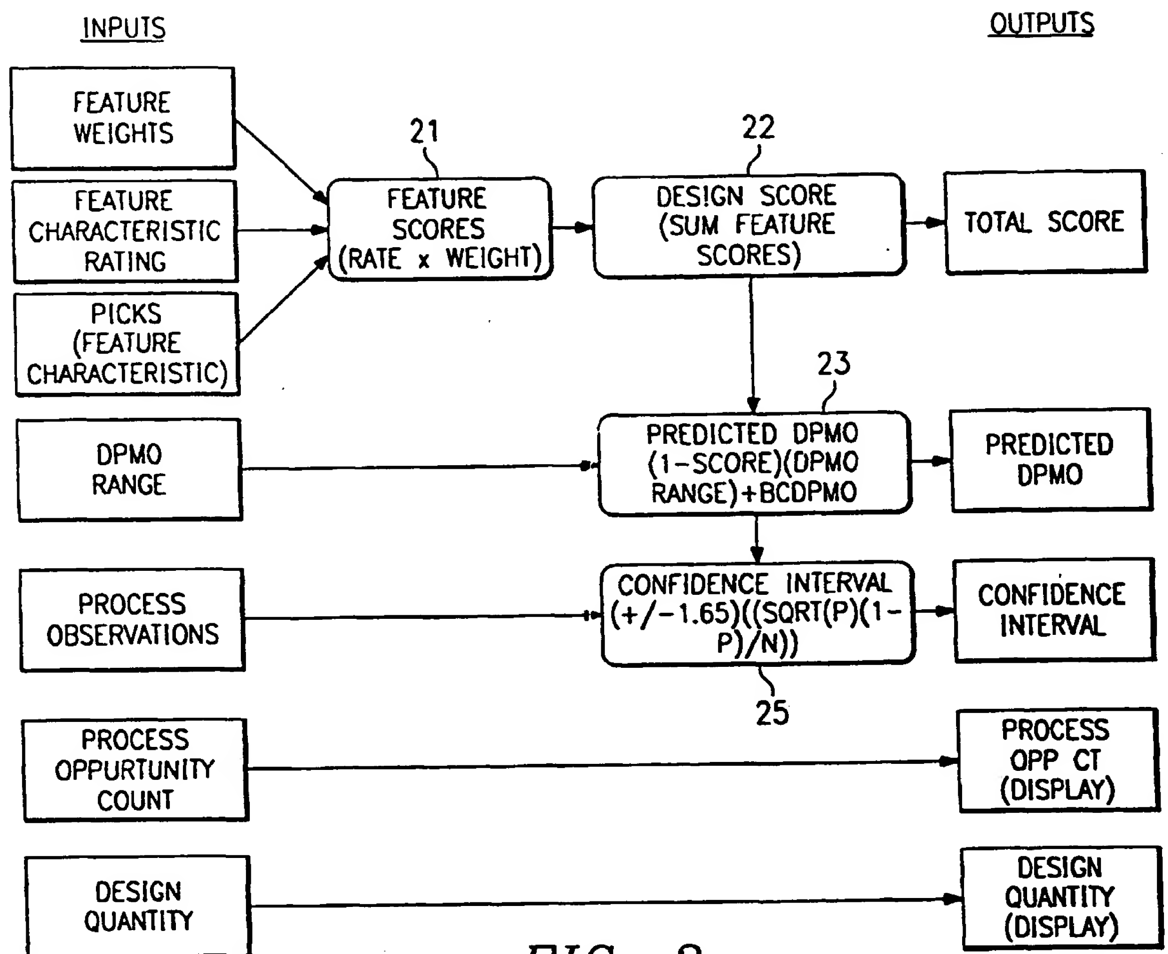

INPUTS
OUTPUTS
FEATURE WEIGHTS
FEATURE CHARACTERISTIC RATING
PICKS (FEATURE CHARACTERISTIC)
21
FEATURE SCORES (RATE x WEIGHT)
22
DESIGN SCORE (SUM FEATURE SCORES)
TOTAL SCORE
23
DPMO RANGE
PREDICTED DPMO (1-SCORE)(DPMO RANGE)+BCDPMO
PREDICTED DPMO
PROCESS OBSERVATIONS
CONFIDENCE INTERVAL (+/-1.65)((SQRT(P)(1-P)/N))
CONFIDENCE INTERVAL
25
PROCESS OPPURTUNITY COUNT
PROCESS OPP CT (DISPLAY)
DESIGN QUANTITY
DESIGN QUANTITY (DISPLAY)

FIG. 2

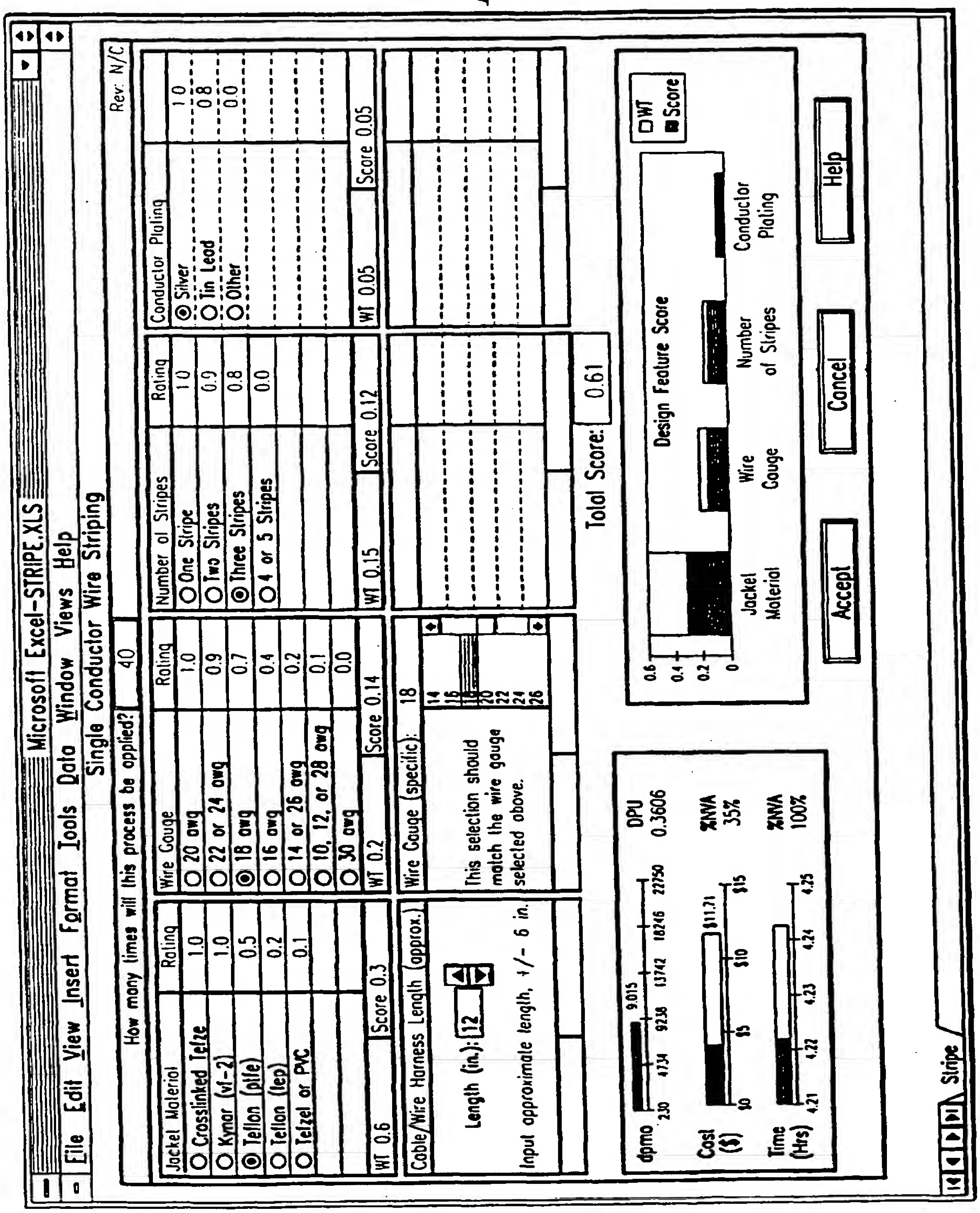
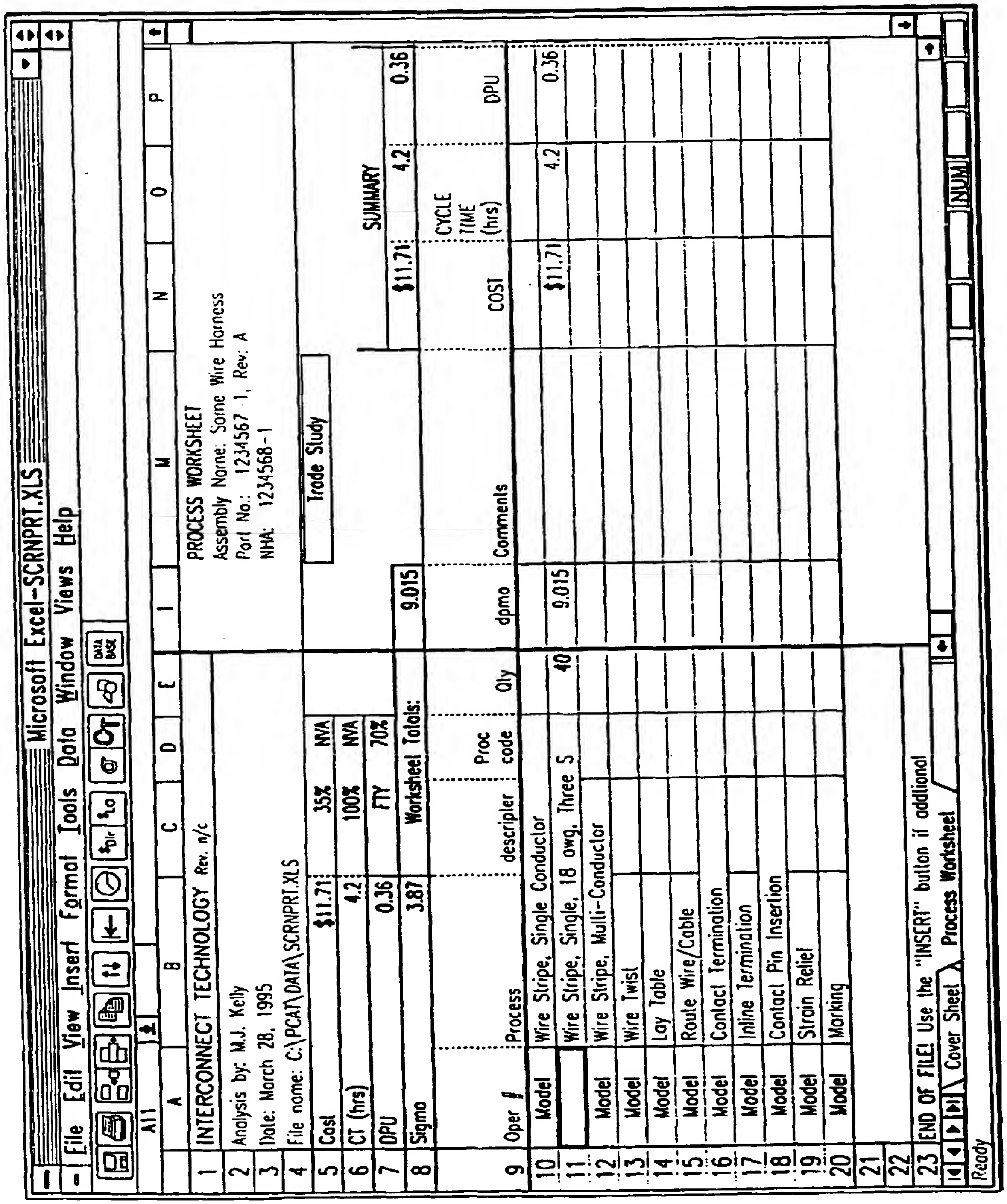

Microsoft Excel-STRIPE.XLS
File Edit View Insert Format Tools Data Window Views Help
Single Conductor Wire Striping
How many times will this process be applied? 40
Rev: N/C
Jacket Material
Rating
Crosslinked Tefze 1.0
Kynar (vf-2) 1.0
Teflon (pfte) 0.5
Teflon (fep) 0.2
Tefzel or PVC 0.1
WT 0.6
Score 0.3
Wire Gauge
Rating
20 awg 1.0
22 or 24 awg 0.9
18 awg 0.7
16 awg 0.4
14 or 26 awg 0.2
10, 12, or 28 awg 0.1
30 awg 0.0
WT 0.2
Score 0.14
Number of Stripes
Rating
One Stripe 1.0
Two Stripes 0.9
Three Stripes 0.8
4 or 5 Stripes 0.0
WT 0.15
Score 0.12
Conductor Plating
Silver 1.0
Tin Lead 0.8
Other 0.0
WT 0.05
Score 0.05
Cable/Wire Harness Length (approx.)
Length (in.): 12
Input approximate length, +/- 6 in.
Wire Gauge (specific): 18
This selection should match the wire gauge selected above.
14
16
18
20
22
24
26
Total Score: 0.61
dpmo
9.015
230 4734 9238 13742 18246 22750
DPU
0.3606
Cost ($)
$11.71
$0 $5 $10 $15
%NVA
35%
Time (Hrs)
4.21 4.22 4.23 4.24 4.25
%NVA
100%
Design Feature Score
0.6
0.4
0.2
0
Jacket Material
Wire Gauge
Number of Stripes
Conductor Plating
WT
Score
Accept
Cancel
Help
Stripe

FIG. 3

FIG. 4



Microsoft Excel-SCRNPRT.XLS
File Edit View Insert Format Tools Data Window Views Help
A11
A B C D E I M N O P
INTERCONNECT TECHNOLOGY Rev. n/c
Analysis by: M.J. Kelly
Date: March 28, 1995
File name: C:\PCAT\DATA\SCRNPRT.XLS
PROCESS WORKSHEET
Assembly Name: Some Wire Harness
Part No.: 1234567-1, Rev: A
NHA: 1234568-1
Trade Study
Cost $11.71 35% NVA
CT (hrs) 4.2 100% NVA
DPU 0.36 FTY 70%
Sigma 3.87 Worksheet Totals: 9.015
SUMMARY
$11.71 4.2 0.36
COST
CYCLE TIME (hrs)
DPU
Oper # Process descripter Proc code Qty dpmo Comments
Model Wire Stripe, Single Conductor 40 9.015 $11.71 4.2 0.36
Wire Stripe, Single, 18 awg, Three S
Model Wire Stripe, Multi-Conductor
Model Wire Twist
Model Lay Table
Model Route Wire/Cable
Model Contact Termination
Model Inline Termination
Model Contact Pin Insertion
Model Strain Relief
Model Marking
END OF FILE! Use the "INSERT" button if addional
Cover Sheet
Process Worksheet
Ready
NUM

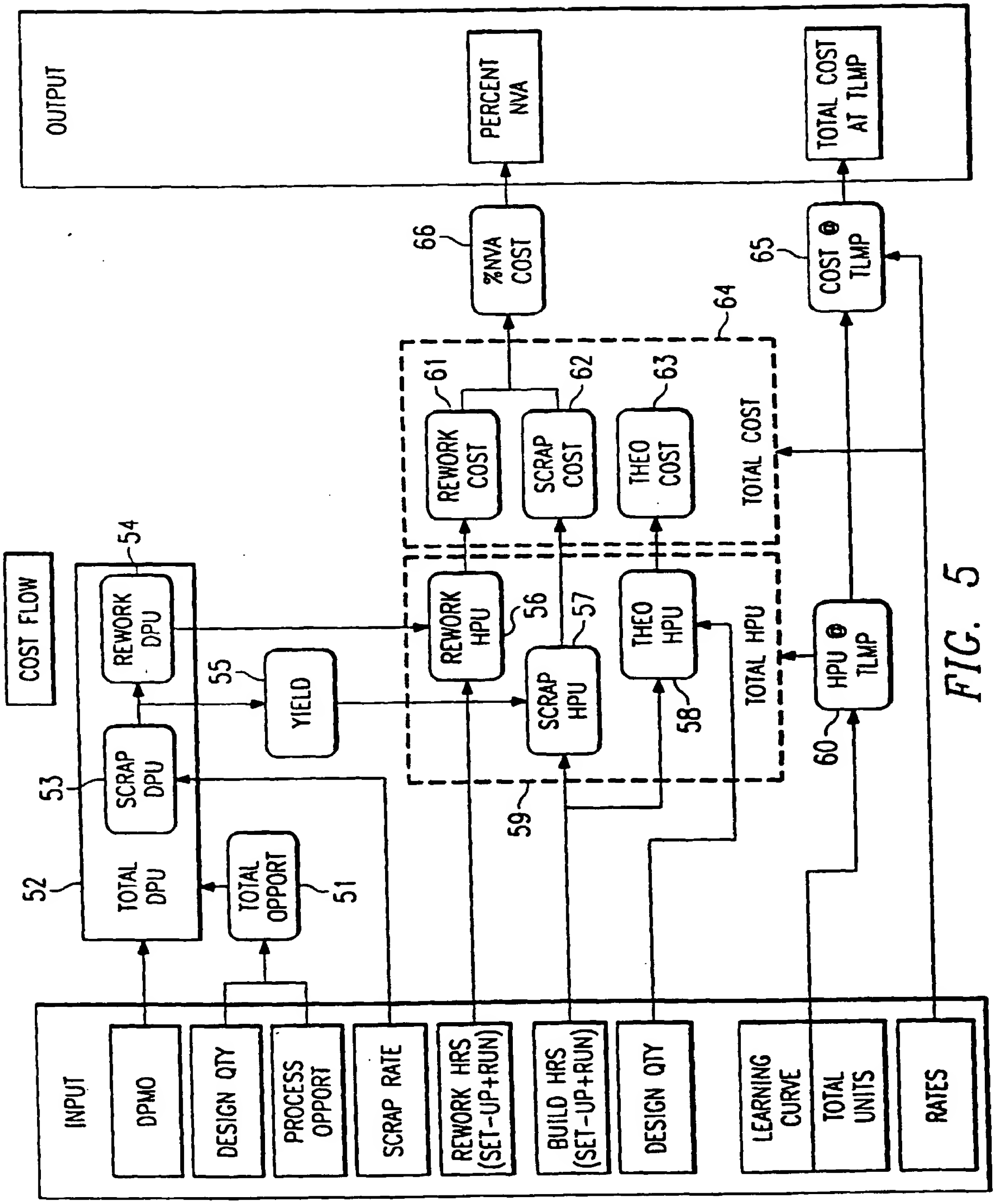

COST FLOW
INPUT
DPMO
DESIGN QTY
PROCESS OPPORT
SCRAP RATE
REWORK HRS (SET-UP+RUN)
BUILD HRS (SET-UP+RUN)
DESIGN QTY
LEARNING CURVE
TOTAL UNITS
RATES
TOTAL OPPORT
51
TOTAL DPU
52
SCRAP DPU
53
REWORK DPU
54
YIELD
55
REWORK HPU
56
SCRAP HPU
57
THEO HPU
58
TOTAL HPU
59
HPU @ TLMP
60
REWORK COST
61
SCRAP COST
62
THEO COST
63
TOTAL COST
64
COST @ TLMP
65
%NVA COST
66
OUTPUT
PERCENT NVA
TOTAL COST AT TLMP

FIG. 5

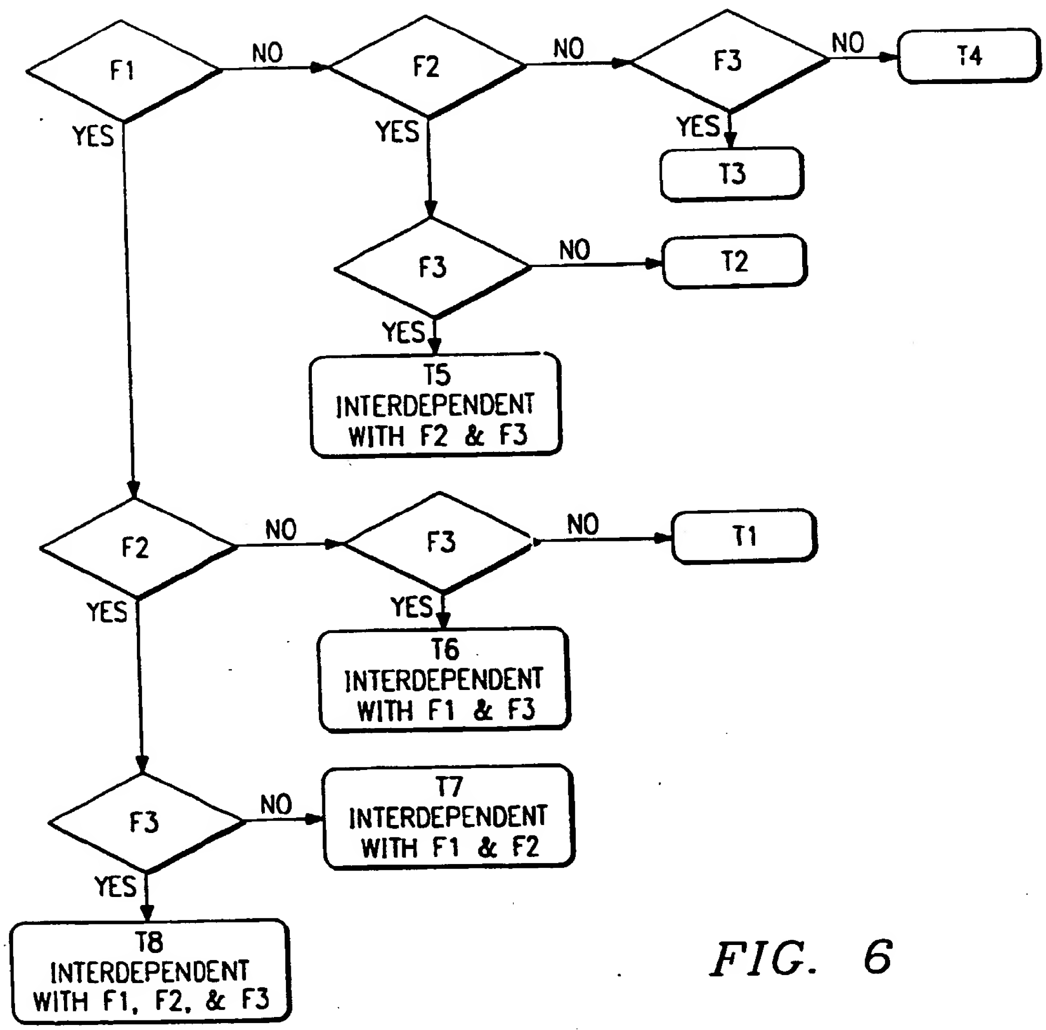

F1
NO
F2
NO
F3
NO
T4
YES
YES
YES
T3
F3
NO
T2
YES
T5
INTERDEPENDENT
WITH F2 & F3
F2
NO
F3
NO
T1
YES
YES
T6
INTERDEPENDENT
WITH F1 & F3
F3
NO
T7
INTERDEPENDENT
WITH F1 & F2
YES
T8
INTERDEPENDENT
WITH F1, F2, & F3

FIG. 6

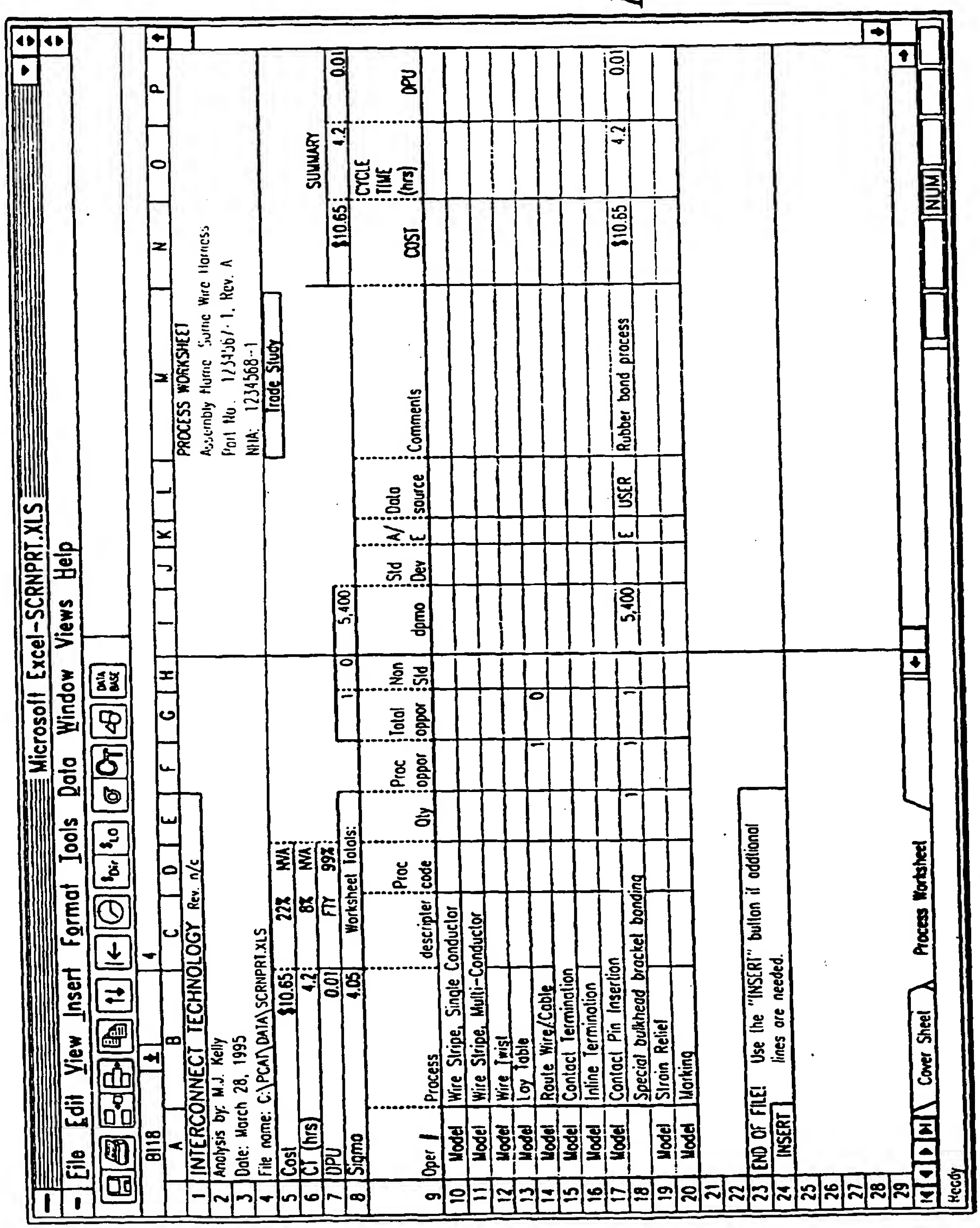

Microsoft Excel-SCRNPRT.XLS
File Edit View Insert Format Tools Data Window Views Help
B118
INTERCONNECT TECHNOLOGY Rev. n/c
Analysis by: M.J. Kelly
Date: March 28, 1995
File name: C:\PCAT\DATA\SCRNPRT.XLS
Cost $10.65 22% NVA
CT (hrs) 4.2 8% NVA
DPU 0.01 FTY 99%
Sigma 4.05 Worksheet Totals:
PROCESS WORKSHEET
Assembly Name Some Wire Harness
Part No. 1234567-1, Rev. A
NHA: 1234568-1
Trade Study
SUMMARY
COST CYCLE TIME (hrs) DPU
$10.65 4.2 0.01
Oper # Process descriptor Proc code Qty Proc oppor Total oppor Non Std dpmo Std Dev A/E Data source Comments
Model Wire Stripe, Single Conductor
Model Wire Stripe, Multi-Conductor
Model Wire Twist
Model Lay Table
Model Route Wire/Cable
Model Contact Termination
Model Inline Termination
Model Contact Pin Insertion 1 1 1 5,400 E USER Rubber bond process $10.65 4.2 0.01
Special bulkhead bracket bonding
Model Strain Relief
Model Marking
END OF FILE! INSERT Use the "INSERT" button if additional lines are needed.
Cover Sheet Process Worksheet
Ready NUM

FIG. 7

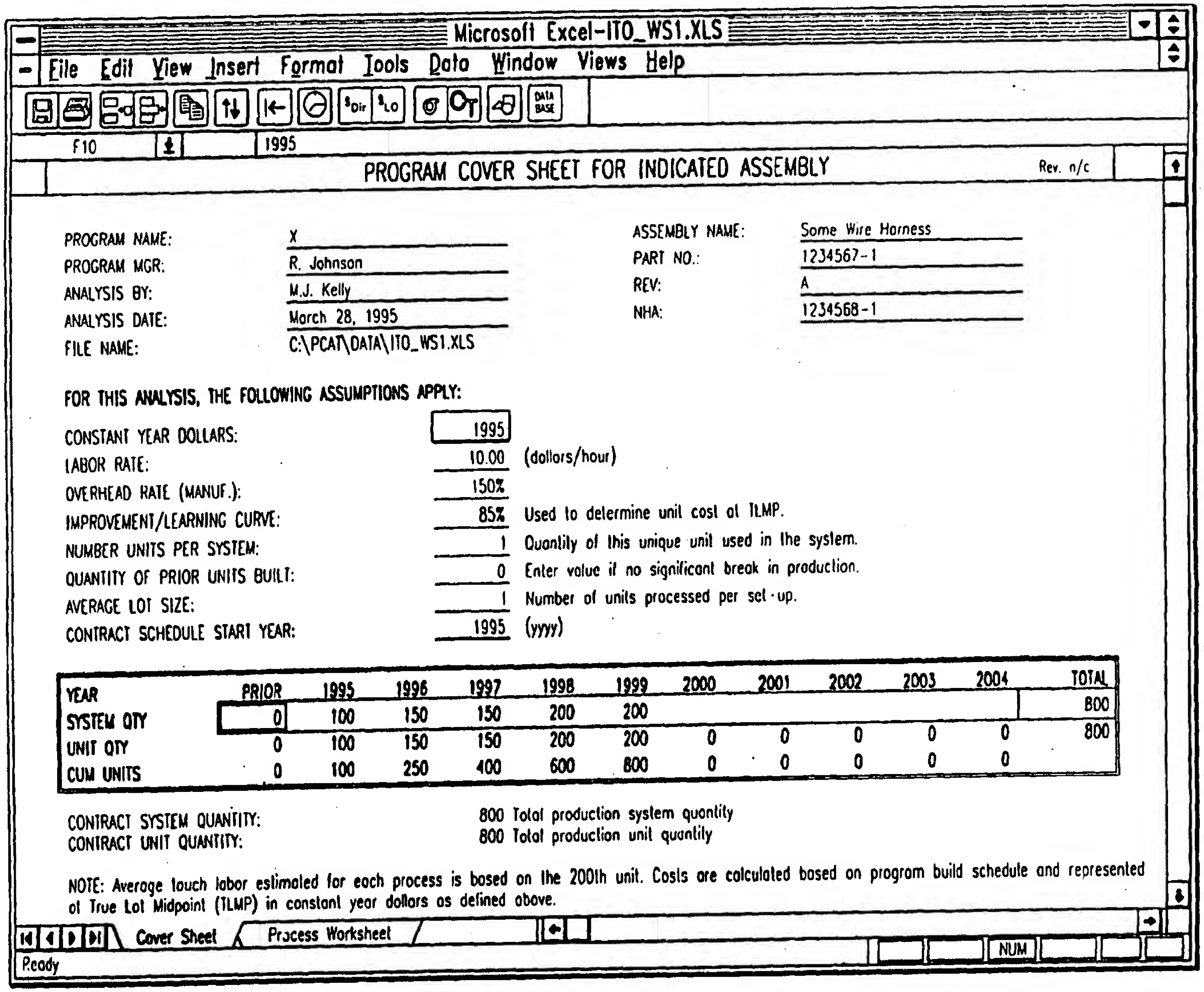
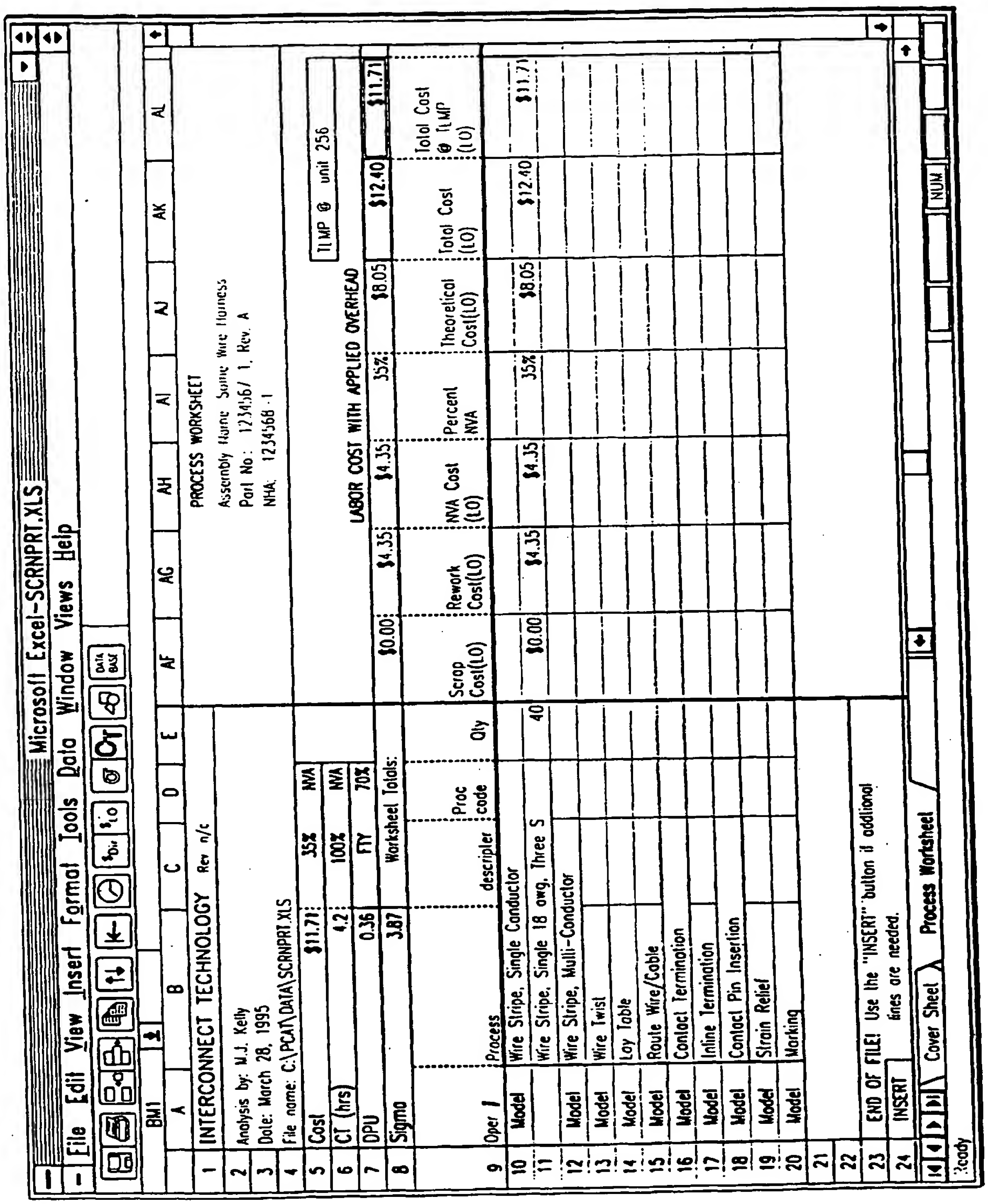

Microsoft Excel-ITO_WS1.XLS
File Edit View Insert Format Tools Data Window Views Help
F10
1995
PROGRAM COVER SHEET FOR INDICATED ASSEMBLY
Rev. n/c
PROGRAM NAME: X
PROGRAM MGR: R. Johnson
ANALYSIS BY: M.J. Kelly
ANALYSIS DATE: March 28, 1995
FILE NAME: C:\PCAT\DATA\ITO_WS1.XLS
ASSEMBLY NAME: Some Wire Harness
PART NO.: 1234567-1
REV: A
NHA: 1234568-1
FOR THIS ANALYSIS, THE FOLLOWING ASSUMPTIONS APPLY:
CONSTANT YEAR DOLLARS: 1995
LABOR RATE: 10.00 (dollars/hour)
OVERHEAD RATE (MANUF.): 150%
IMPROVEMENT/LEARNING CURVE: 85% Used to determine unit cost at TLMP.
NUMBER UNITS PER SYSTEM: 1 Quantity of this unique unit used in the system.
QUANTITY OF PRIOR UNITS BUILT: 0 Enter value if no significant break in production.
AVERAGE LOT SIZE: 1 Number of units processed per set-up.
CONTRACT SCHEDULE START YEAR: 1995 (yyyy)
YEAR PRIOR 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 TOTAL
SYSTEM QTY 0 100 150 150 200 200 800
UNIT QTY 0 100 150 150 200 200 0 0 0 0 0 800
CUM UNITS 0 100 250 400 600 800 0 0 0 0 0
CONTRACT SYSTEM QUANTITY: 800 Total production system quantity
CONTRACT UNIT QUANTITY: 800 Total production unit quantity
NOTE: Average touch labor estimated for each process is based on the 200th unit. Costs are calculated based on program build schedule and represented at True Lot Midpoint (TLMP) in constant year dollars as defined above.
Cover Sheet
Process Worksheet
NUM
Ready

FIG. 8

FIG. 9


Microsoft Excel-SCRNPRT.XLS
File Edit View Insert Format Tools Data Window Views Help
INTERCONNECT TECHNOLOGY Rev n/c
Analysis by: M.J. Kelly
Date: March 28, 1995
File name: C:\PCAT\DATA\SCRNPRT.XLS
Cost $11.71 35% NVA
CT (hrs) 4.2 100% NVA
DPU 0.36 FTY 70%
Sigma 3.87 Worksheet Totals:
PROCESS WORKSHEET
Assembly Name Some Wire Harness
Part No: 1234567 1, Rev. A
NHA: 1234568-1
LABOR COST WITH APPLIED OVERHEAD
TLMP @ unit 256
$0.00 $4.35 $4.35 35% $8.05 $12.40 $11.71
Oper # Process descripter Proc code Qty Scrap Cost(LO) Rework Cost(LO) NVA Cost (LO) Percent NVA Theoretical Cost(LO) Total Cost (LO) Total Cost @ TLMP (LO)
Model Wire Stripe, Single Conductor
Wire Stripe, Single 18 awg, Three S 40 $0.00 $4.35 $4.35 35% $8.05 $12.40 $11.71
Model Wire Stripe, Muli-Conductor
Model Wire Twist
Model Lay Table
Model Route Wire/Cable
Model Contact Termination
Model Inline Termination
Model Contact Pin Insertion
Model Strain Relief
Model Marking
END OF FILE! Use the "INSERT" button if addional lines are needed.
INSERT
Cover Sheet Process Worksheet
Ready NUM

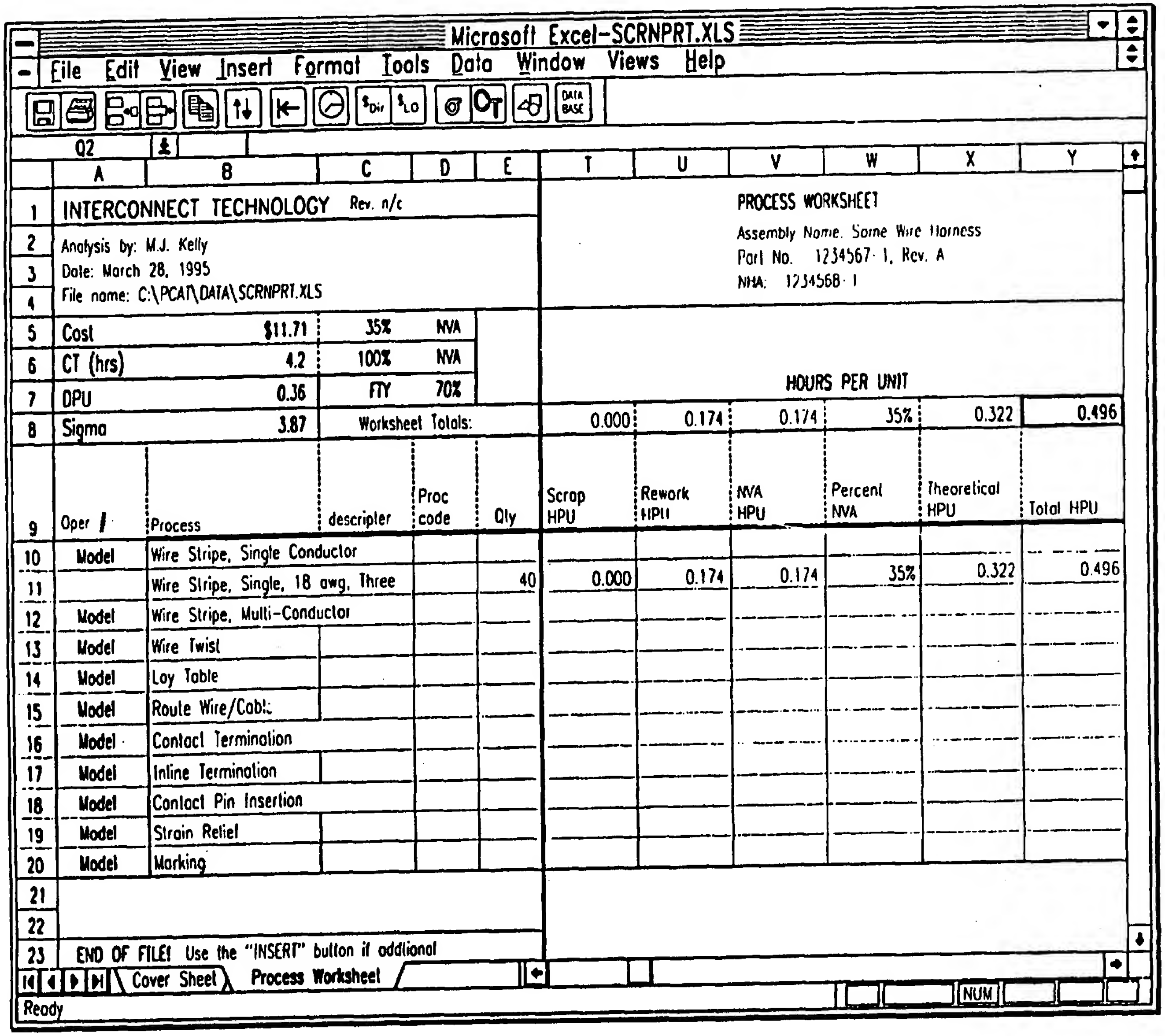

Microsoft Excel-SCRNPRT.XLS
File Edit View Insert Format Tools Data Window Views Help
DATA BASE
Q2
A B C D E T U V W X Y
INTERCONNECT TECHNOLOGY Rev. n/c
Analysis by: M.J. Kelly
Date: March 28, 1995
File name: C:\PCAT\DATA\SCRNPRT.XLS
PROCESS WORKSHEET
Assembly Name. Some Wire Harness
Part No. 1234567-1, Rev. A
NHA: 1234568-1
Cost $11.71 35% NVA
CT (hrs) 4.2 100% NVA
DPU 0.36 FTY 70%
Sigma 3.87 Worksheet Totals:
HOURS PER UNIT
0.000 0.174 0.174 35% 0.322 0.496
Oper # Process descripter Proc code Qty
Scrap HPU Rework HPU NVA HPU Percent NVA Theoretical HPU Total HPU
Model Wire Stripe, Single Conductor
Wire Stripe, Single, 18 awg, Three 40 0.000 0.174 0.174 35% 0.322 0.496
Model Wire Stripe, Multi-Conductor
Model Wire Twist
Model Lay Table
Model Route Wire/Cabl:
Model Contact Termination
Model Inline Termination
Model Contact Pin Insertion
Model Strain Relief
Model Marking
END OF FILE! Use the "INSERT" button if addional
Cover Sheet
Process Worksheet
NUM
Ready

FIG. 10

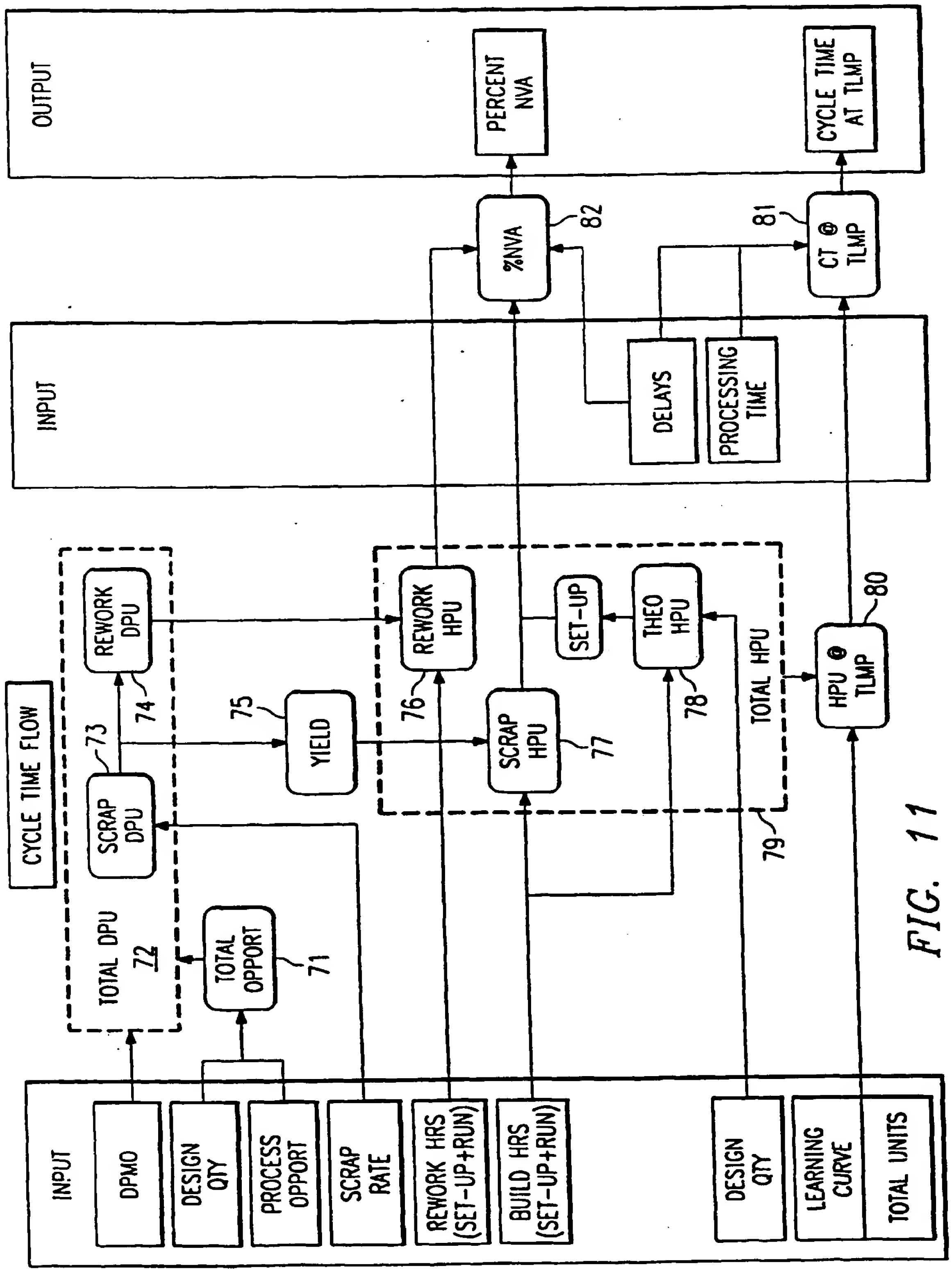
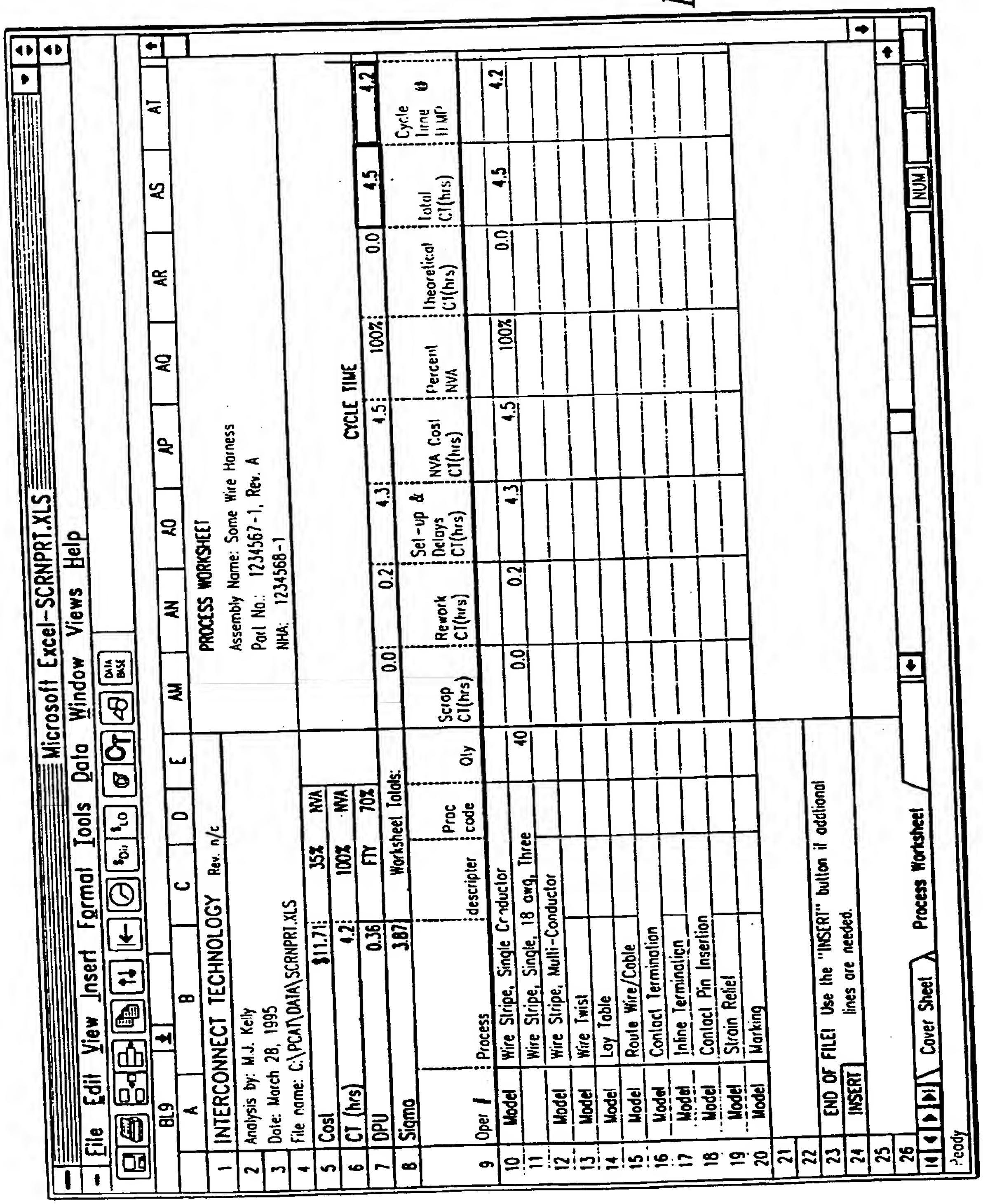

CYCLE TIME FLOW
INPUT
DPMO
DESIGN QTY
PROCESS OPPORT
SCRAP RATE
REWORK HRS (SET-UP+RUN)
BUILD HRS (SET-UP+RUN)
DESIGN QTY
LEARNING CURVE
TOTAL UNITS
TOTAL OPPORT
71
TOTAL DPU
72
SCRAP DPU
73
REWORK DPU
74
YIELD
75
REWORK HPU
76
SCRAP HPU
77
SET-UP
THEO HPU
78
TOTAL HPU
79
HPU @ TLMP
80
INPUT
DELAYS
PROCESSING TIME
%NVA
82
CT @ TLMP
81
OUTPUT
PERCENT NVA
CYCLE TIME AT TLMP

FIG. 11



Microsoft Excel-SCRNPRT.XLS
File Edit View Insert Format Tools Data Window Views Help
BL9
A B C D E AM AN AO AP AQ AR AS AT
INTERCONNECT TECHNOLOGY Rev. n/c
Analysis by: M.J. Kelly
Date: March 28, 1995
File name: C:\PCAT\DATA\SCRNPRT.XLS
PROCESS WORKSHEET
Assembly Name: Some Wire Harness
Part No.: 1234567-1, Rev. A
NHA: 1234568-1
Cost $11.71 35% NVA
CT (hrs) 4.2 100% NVA
DPU 0.36 FTY 70%
Sigma 3.87 Worksheet Totals:
CYCLE TIME
0.0 0.2 4.3 4.5 100% 0.0 4.5 4.2
Oper # Process descripter Proc code Qty Scrap CT(hrs) Rework CT(hrs) Set-up & Delays CT(hrs) NVA Cost CT(hrs) Percent NVA Theoretical CT(hrs) Total CT(hrs) Cycle time @ 11 MP
Model Wire Stripe, Single Conductor 40 0.0 0.2 4.3 4.5 100% 0.0 4.5 4.2
Wire Stripe, Single, 18 awg, Three
Model Wire Stripe, Multi-Conductor
Model Wire Twist
Model Lay Table
Model Route Wire/Cable
Model Contact Termination
Model Inline Termination
Model Contact Pin Insertion
Model Strain Relief
Model Marking
END OF FILE! Use the "INSERT" button if additional lines are needed.
INSERT
Cover Sheet
Process Worksheet
Ready
NUM

FIG. 12

INTERCONNECT TECHNOLOGY Rev. PT-5

Analysis by: M.J. Kelly
Date: March 28, 1995
File name: C:\PCAT\DATA\ITO_WS1.XLS

PROCESS WORKSHEET
Assembly Name: Wire Harness
Part No.: 1234567-0001, Rev n/c
NHA. 1234568-0001

Trade Study

Cost	$240.90:	19%	NVA
CT (hrs)	33.2:	57%	NVA
DPU	1.26	FTY	28%
Sigma	4.11	Worksheet Totals:	4,554

Oper #	Process	descriptor	Proc code	Qty	dpmo	Comments	COST	CYCLE TIME (hrs)	DPU
						SUMMARY	$240.90	33.2	1.26
PC Model	Wire Stripe, Single Conductor						$15.29	5.8	0.27
	Wire Stripe, Single, 18 awg, Three Str			30	9,015		$7.04	5.5	0.16
	Wire Stripe, Single, 24 awg, Two Strip			21	7,776		$5.75	5.5	0.07
	Wire Stripe, Single, 24 awg, One Strip			9	7,438				
PC Model	Wire Stripe, Multi-Conductor								
PC Model	Wire Twist						$9.95	0.4	0.01
	Wire Twisting, 3 to 4.5 per inch, 20			2	2,733		$10.18	0.4	0.01
	Wire Twisting, 1 to 2.5 per inch, 18			6	1,823				
PC Model	Lay Table						$29.40	1.2	0.00
Route	Route Wire/Cable			1	50		$4.55	0.2	0.00
Tape	Tape Segment			12	50		$0.00	0.0	0.00
Flat Lace	Flat Lace Segment				1,000		$0.00	0.0	0.00
	Install Braid Segment				50		$0.00	0.0	0.00
Non-shrink	Non-shrink Sleeve Segment				50		$0.89	0.0	0.00
Shrink Slv	Shrink Sleeve Segment			2	50		$1.52	0.1	0.00
	Cable Tie			8	50		$0.00	0.0	0.00
	Lacing Cord				230				
PC Model	Contact Termination						$76.82	3.1	0.61
	Contact Termination, Solder, 16-18, 2			60	10,240		$12.35	0.5	0.00
	Contact Termination, Crimp, 22 to 26			60	3				
PC Model	Inline Termination								
PC Model	Contact Pin Insertion						$39.33	1.6	0.00
	Contact Insertion, 26 to 55, Grid/Num			2	1,144				
PC Model	Strain Relief						$23.24	8.8	0.01
	Strain Relief, RTV potting, min, max,			2	5,463		$4.56	0.2	0.11
	Strain Relief, Sleeve (sngl wire), min,n			60	1,823				
PC Model	Marking						$0.03	0.0	0.00
	Sym. Bandmaker, Typewriter (paper).			1	1,368				

FIG. 13

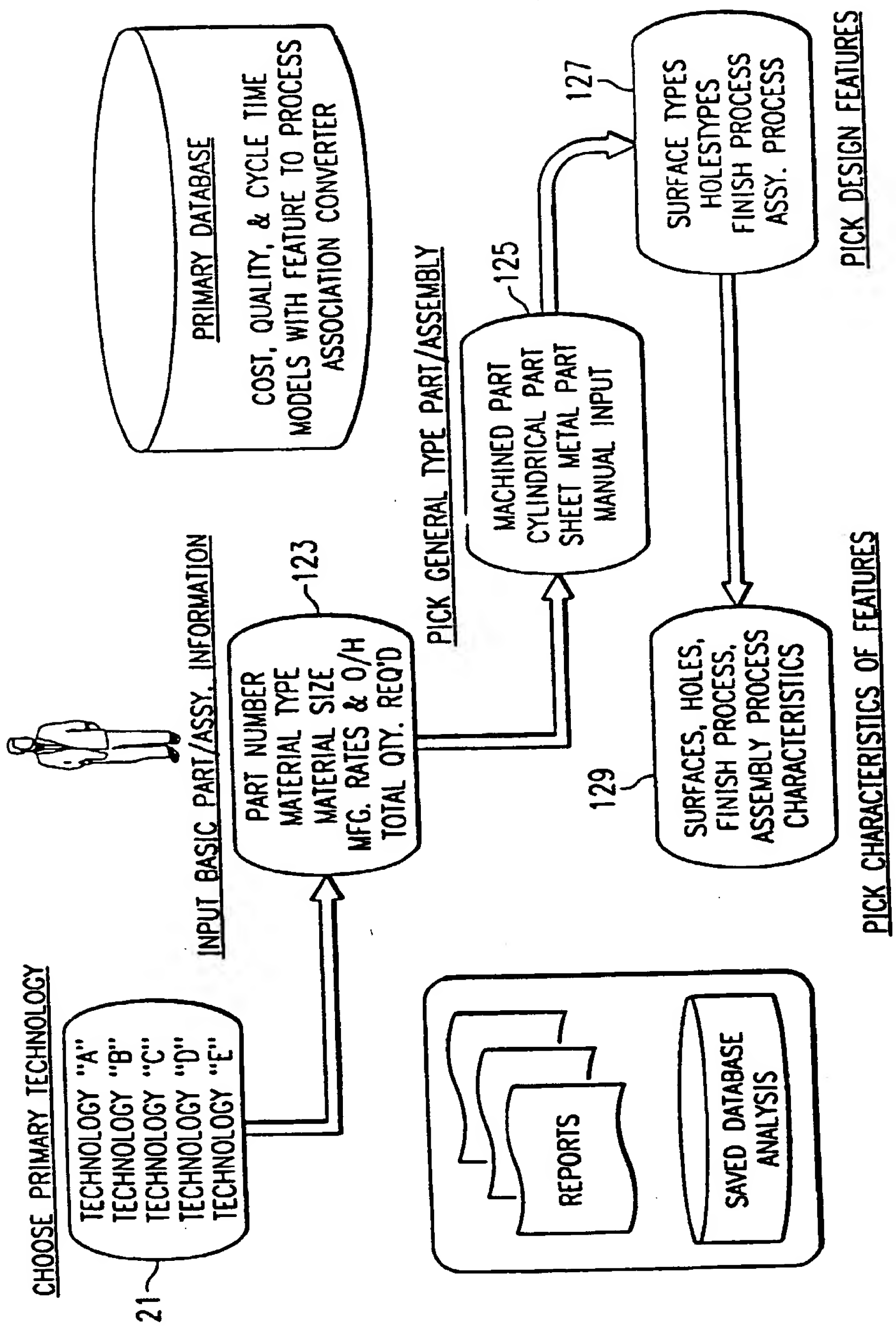

CHOOSE PRIMARY TECHNOLOGY
121
TECHNOLOGY "A"
TECHNOLOGY "B"
TECHNOLOGY "C"
TECHNOLOGY "D"
TECHNOLOGY "E"
INPUT BASIC PART/ASSY. INFORMATION
123
PART NUMBER
MATERIAL TYPE
MATERIAL SIZE
MFG. RATES & O/H
TOTAL QTY. REQ'D
PRIMARY DATABASE
COST, QUALITY, & CYCLE TIME
MODELS WITH FEATURE TO PROCESS
ASSOCIATION CONVERTER
PICK GENERAL TYPE PART/ASSEMBLY
125
MACHINED PART
CYLINDRICAL PART
SHEET METAL PART
MANUAL INPUT
127
SURFACE TYPES
HOLESTYPES
FINISH PROCESS
ASSY. PROCESS
PICK DESIGN FEATURES
129
SURFACES, HOLES,
FINISH PROCESS,
ASSEMBLY PROCESS
CHARACTERISTICS
PICK CHARACTERISTICS OF FEATURES
REPORTS
SAVED DATABASE
ANALYSIS

FIG. 14

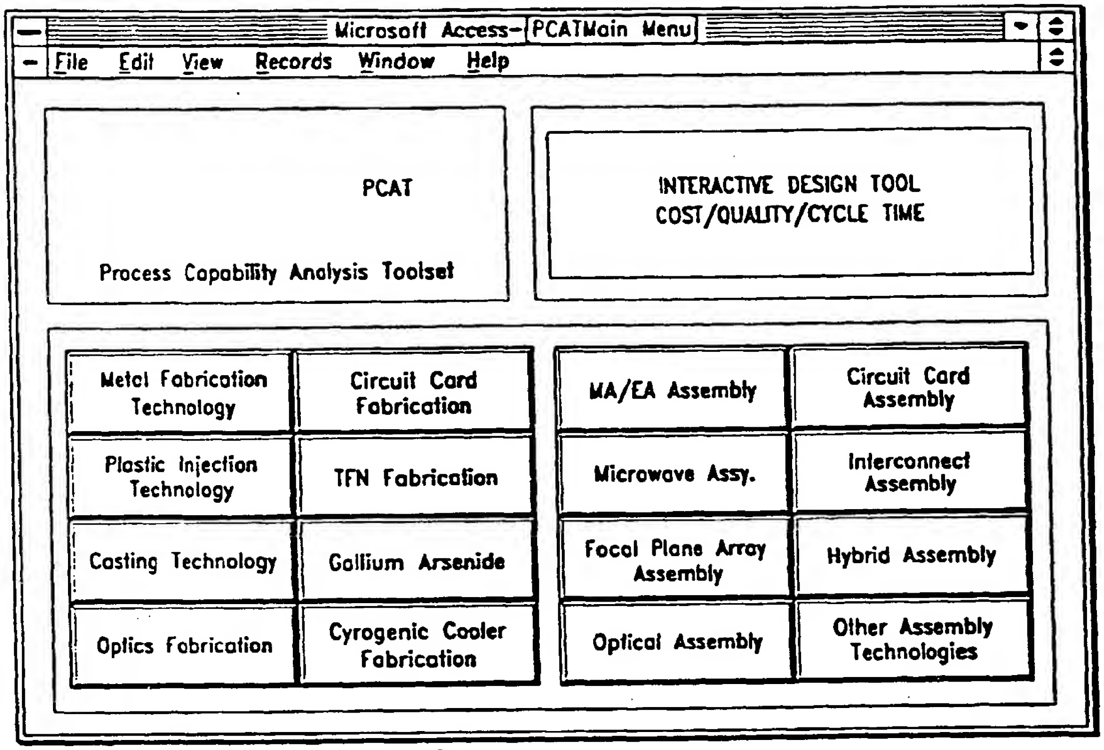
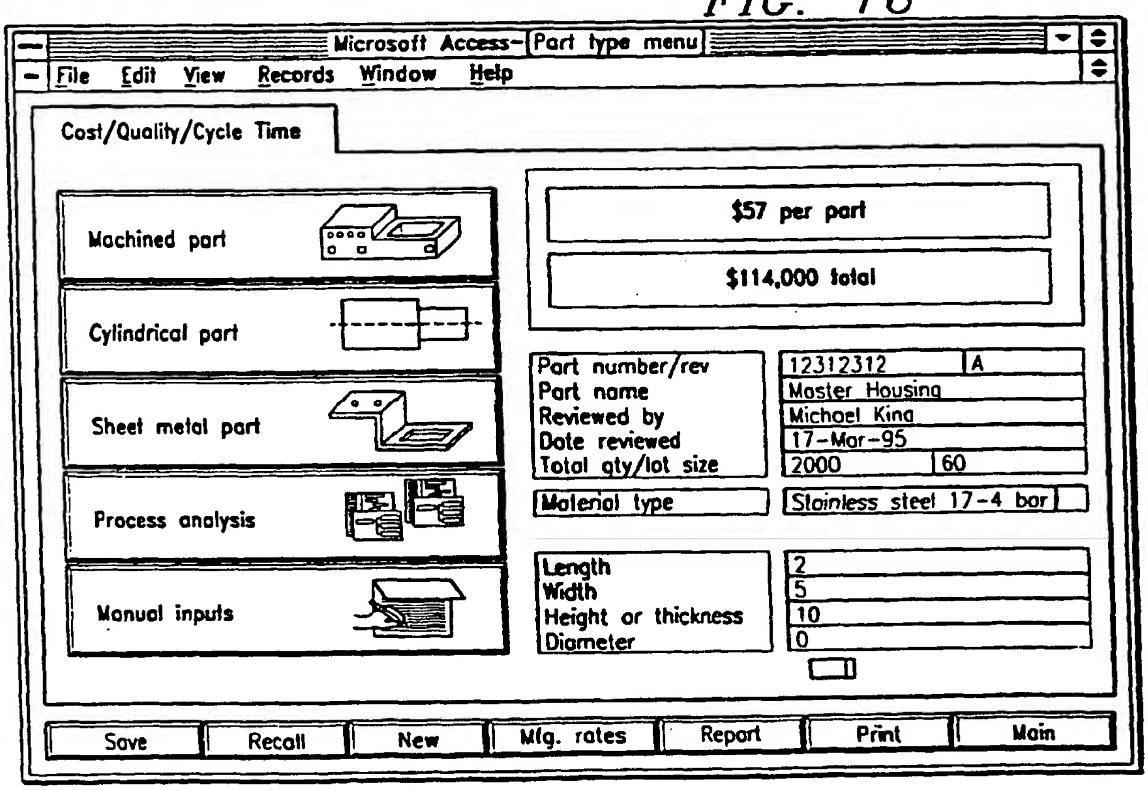
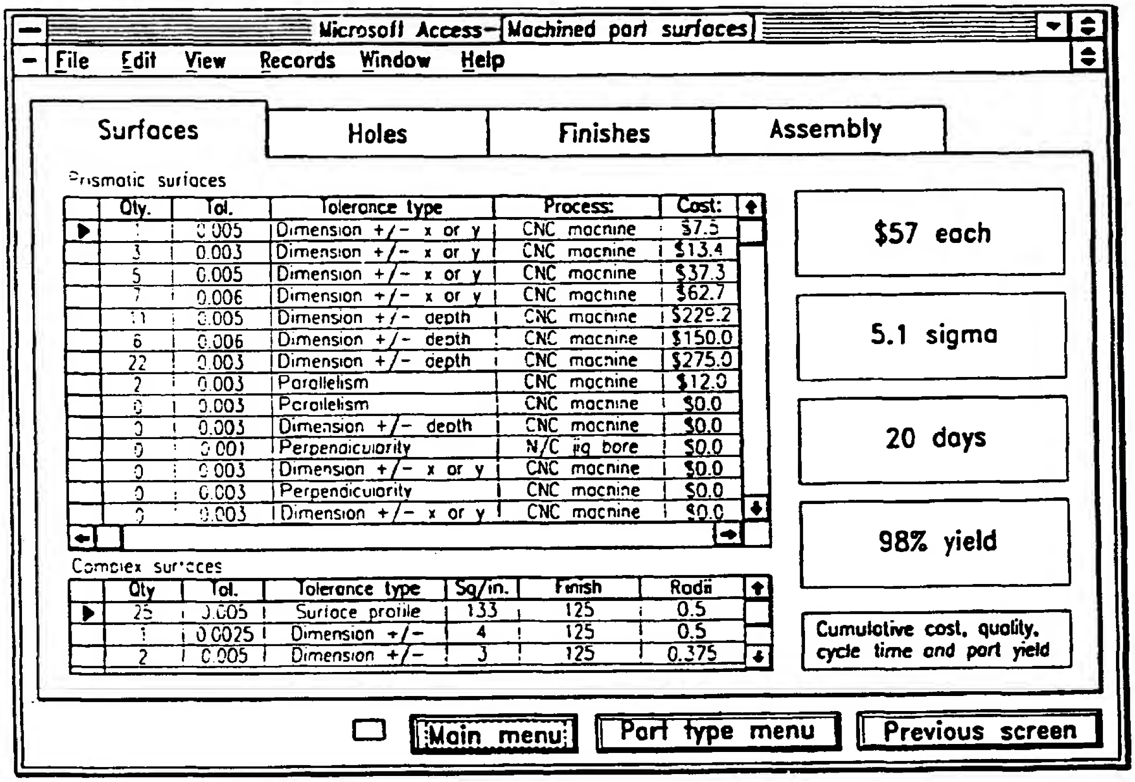

Microsoft Access-[PCATMain Menu]
File Edit View Records Window Help
PCAT
Process Capability Analysis Toolset
INTERACTIVE DESIGN TOOL
COST/QUALITY/CYCLE TIME
Metal Fabrication Technology
Circuit Card Fabrication
MA/EA Assembly
Circuit Card Assembly
Plastic Injection Technology
TFN Fabrication
Microwave Assy.
Interconnect Assembly
Casting Technology
Gallium Arsenide
Focal Plane Array Assembly
Hybrid Assembly
Optics Fabrication
Cyrogenic Cooler Fabrication
Optical Assembly
Other Assembly Technologies

FIG. 15

FIG. 16


Microsoft Access-[Part type menu]
File Edit View Records Window Help
Cost/Quality/Cycle Time
Machined part
Cylindrical part
Sheet metal part
Process analysis
Manual inputs
$57 per part
$114,000 total
Part number/rev
Part name
Reviewed by
Date reviewed
Total qty/lot size
12312312
A
Master Housing
Michael King
17-Mar-95
2000
60
Material type
Stainless steel 17-4 bar
Length
Width
Height or thickness
Diameter
2
5
10
0
Save
Recall
New
Mfg. rates
Report
Print
Main


Microsoft Access–Machined part surfaces
File Edit View Records Window Help
Surfaces
Holes
Finishes
Assembly
Prismatic surfaces

Qty.	Tol.	Tolerance type	Process:	Cost:
1	0.005	Dimension +/– x or y	CNC machine	$7.5
3	0.003	Dimension +/– x or y	CNC machine	$13.4
5	0.005	Dimension +/– x or y	CNC machine	$37.3
7	0.006	Dimension +/– x or y	CNC machine	$62.7
11	0.005	Dimension +/– depth	CNC machine	$229.2
6	0.006	Dimension +/– depth	CNC machine	$150.0
22	0.003	Dimension +/– depth	CNC machine	$275.0
2	0.003	Parallelism	CNC machine	$12.0
0	0.003	Parallelism	CNC machine	$0.0
0	0.003	Dimension +/– depth	CNC machine	$0.0
0	0.001	Perpendicularity	N/C jig bore	$0.0
0	0.003	Dimension +/– x or y	CNC machine	$0.0
0	0.003	Perpendicularity	CNC machine	$0.0
0	0.003	Dimension +/– x or y	CNC machine	$0.0

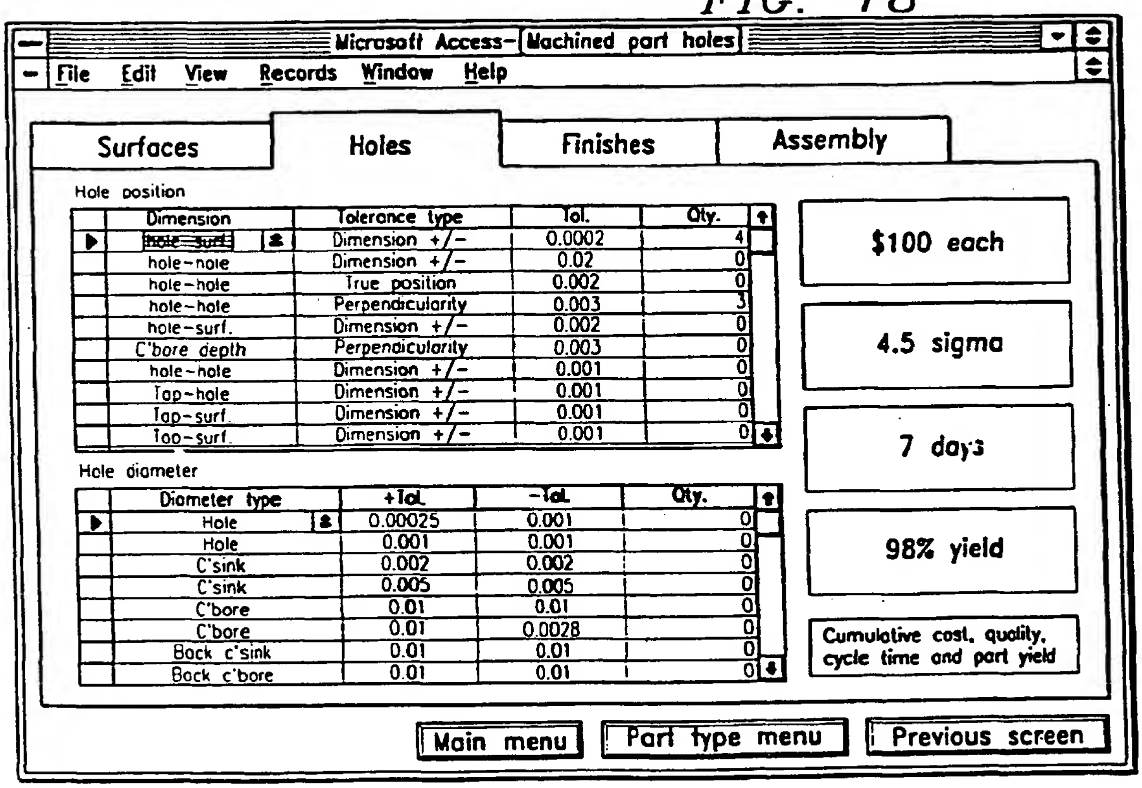
Complex surfaces

Qty	Tol.	Tolerance type	Sq/in.	Finish	Radii
25	0.005	Surface profile	133	125	0.5
1	0.0025	Dimension +/–	4	125	0.5
2	0.005	Dimension +/–	3	125	0.375

$57 each
5.1 sigma
20 days
98% yield
Cumulative cost, quality, cycle time and part yield
Main menu
Part type menu
Previous screen

FIG. 17

FIG. 18


Microsoft Access–Machined part holes
File Edit View Records Window Help
Surfaces
Holes
Finishes
Assembly
Hole position

Dimension	Tolerance type	Tol.	Qty.
~~hole-surf~~	Dimension +/–	0.0002	4
hole–hole	Dimension +/–	0.02	0
hole–hole	True position	0.002	0
hole–hole	Perpendicularity	0.003	3
hole–surf.	Dimension +/–	0.002	0
C'bore depth	Perpendicularity	0.003	0
hole–hole	Dimension +/–	0.001	0
Tap–hole	Dimension +/–	0.001	0
Tap–surf.	Dimension +/–	0.001	0
Tap–surf.	Dimension +/–	0.001	0

Hole diameter

Diameter type	+Tol.	–Tol.	Qty.
Hole	0.00025	0.001	0
Hole	0.001	0.001	0
C'sink	0.002	0.002	0
C'sink	0.005	0.005	0
C'bore	0.01	0.01	0
C'bore	0.01	0.0028	0
Back c'sink	0.01	0.01	0
Back c'bore	0.01	0.01	0

$100 each
4.5 sigma
7 days
98% yield
Cumulative cost, quality, cycle time and part yield
Main menu
Part type menu
Previous screen

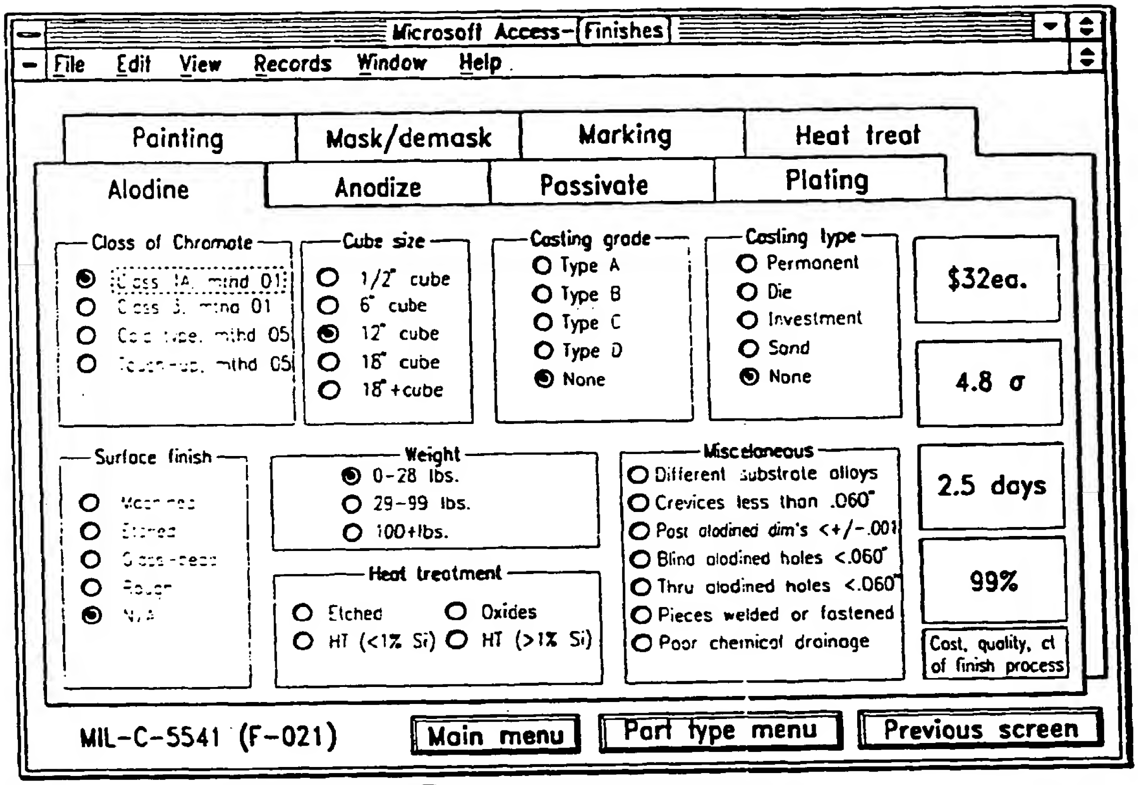
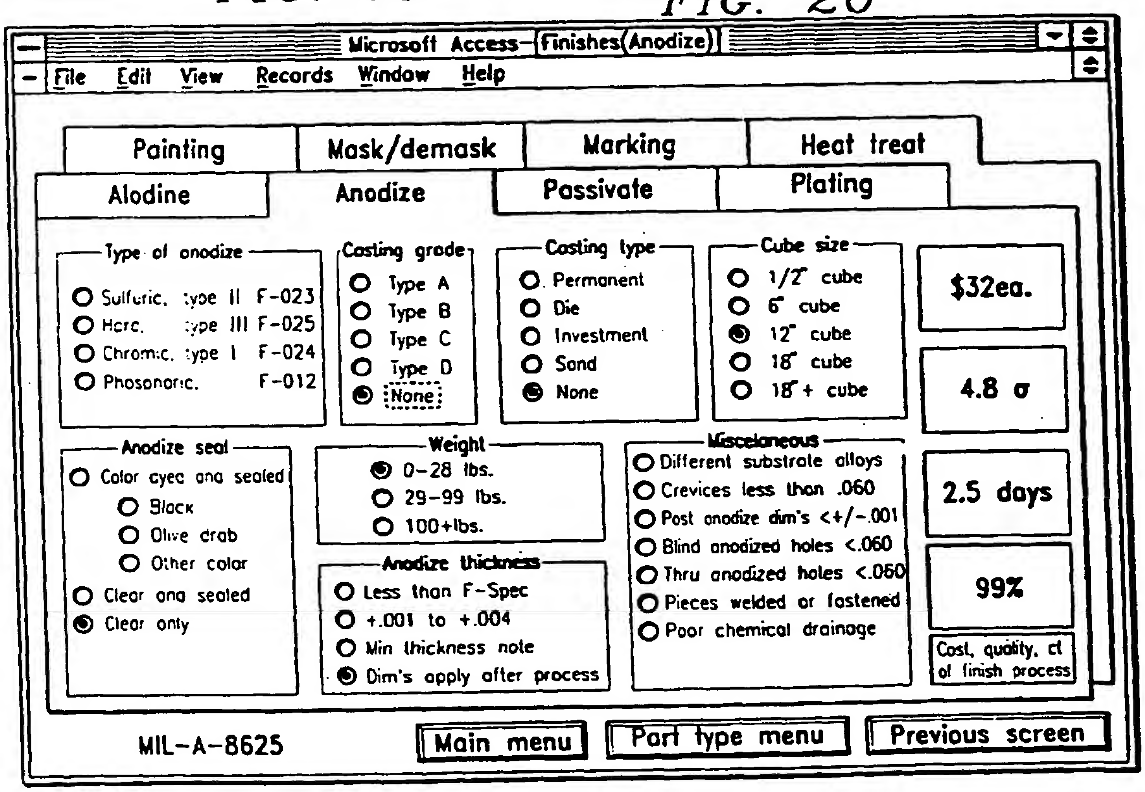

Microsoft Access-[Finishes]
File Edit View Records Window Help
Painting
Mask/demask
Marking
Heat treat
Alodine
Anodize
Passivate
Plating
Class of Chromate
Cube size
1/2" cube
6" cube
12" cube
18" cube
18"+cube
Casting grade
Type A
Type B
Type C
Type D
None
Casting type
Permanent
Die
Investment
Sand
None
$32ea.
4.8 σ
Surface finish
Weight
0-28 lbs.
29-99 lbs.
100+lbs.
Heat treatment
Etched
Oxides
HT (<1% Si)
HT (>1% Si)
Miscelaneous
Different substrate alloys
Crevices less than .060"
Post alodined dim's <+/-.001
Blind alodined holes <.060"
Thru alodined holes <.060"
Pieces welded or fastened
Poor chemical drainage
2.5 days
99%
Cost, quality, ct of finish process
MIL-C-5541 (F-021)
Main menu
Part type menu
Previous screen

FIG. 19

FIG. 20


Microsoft Access-[Finishes(Anodize)]
File Edit View Records Window Help
Painting
Mask/demask
Marking
Heat treat
Alodine
Anodize
Passivate
Plating
Type of anodize
Sulfuric, type II F-023
Hard, type III F-025
Chromic, type I F-024
Phosphoric F-012
Casting grade
Type A
Type B
Type C
Type D
None
Casting type
Permanent
Die
Investment
Sand
None
Cube size
1/2" cube
6" cube
12" cube
18" cube
18"+ cube
$32ea.
4.8 σ
Anodize seal
Color dyed and sealed
Black
Olive drab
Other color
Clear and sealed
Clear only
Weight
0-28 lbs.
29-99 lbs.
100+lbs.
Anodize thickness
Less than F-Spec
+.001 to +.004
Min thickness note
Dim's apply after process
Miscelaneous
Different substrate alloys
Crevices less than .060
Post anodize dim's <+/-.001
Blind anodized holes <.060
Thru anodized holes <.060
Pieces welded or fastened
Poor chemical drainage
2.5 days
99%
Cost, quality, ct of finish process
MIL-A-8625
Main menu
Part type menu
Previous screen

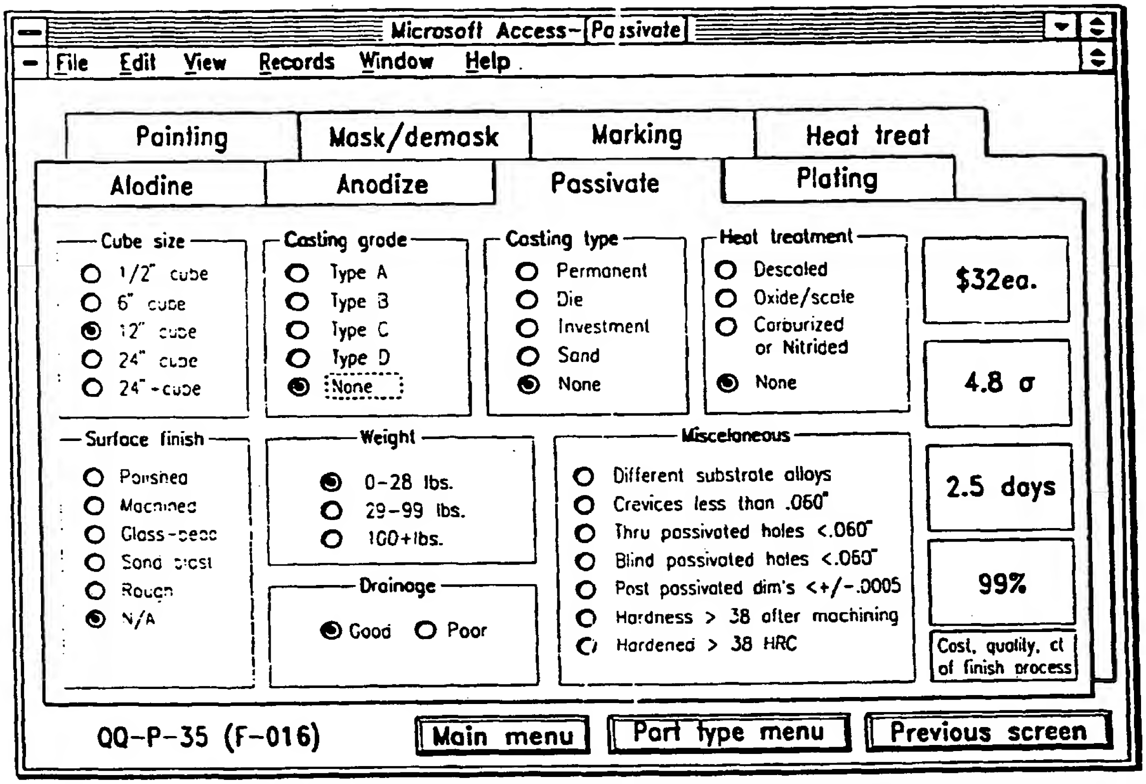
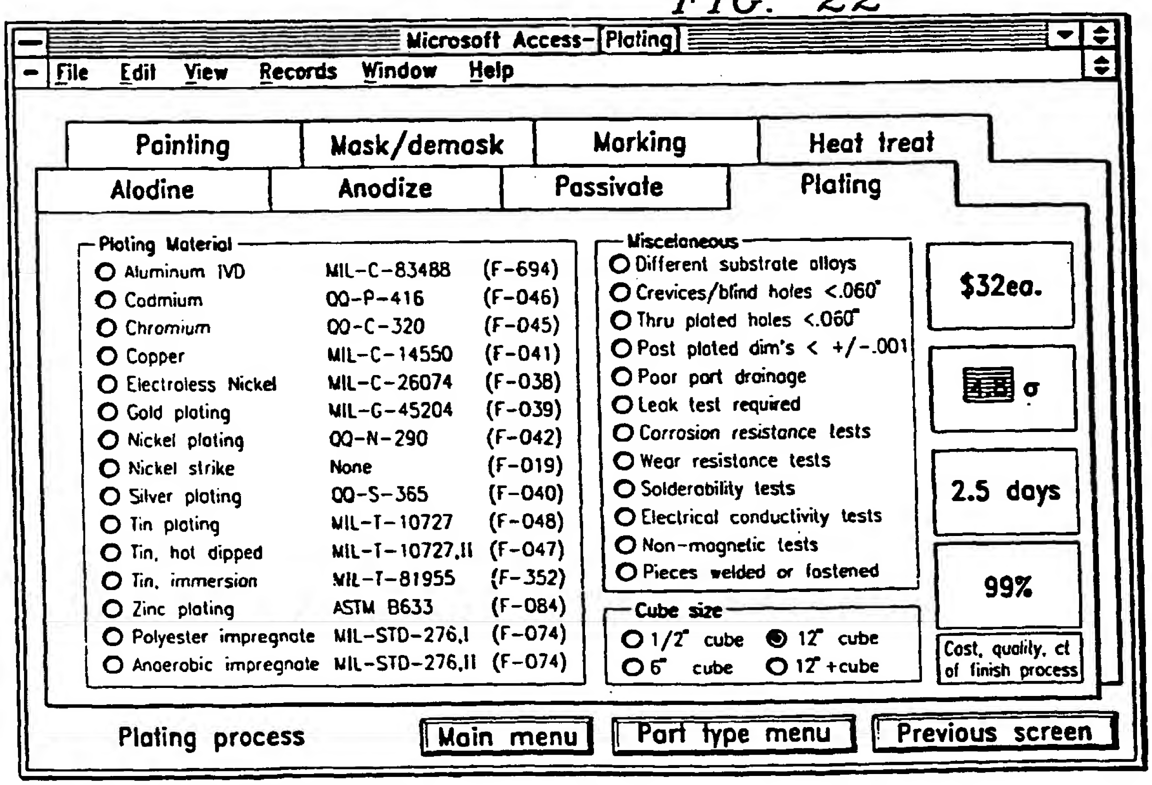

Microsoft Access-[Passivate]
File Edit View Records Window Help
Painting
Mask/demask
Marking
Heat treat
Alodine
Anodize
Passivate
Plating
Cube size
1/2" cube
6" cube
12" cube
24" cube
24"-cube
Casting grade
Type A
Type B
Type C
Type D
None
Casting type
Permanent
Die
Investment
Sand
None
Heat treatment
Descaled
Oxide/scale
Carburized or Nitrided
None
$32ea.
4.8 σ
Surface finish
Polished
Machined
Glass-bead
Sand blast
Rough
N/A
Weight
0-28 lbs.
29-99 lbs.
100+lbs.
Drainage
Good
Poor
Miscelaneous
Different substrate alloys
Crevices less than .060"
Thru passivated holes <.060"
Blind passivated holes <.060"
Post passivated dim's <+/-.0005
Hardness > 38 after machining
Hardened > 38 HRC
2.5 days
99%
Cost, quality, ct of finish process
QQ-P-35 (F-016)
Main menu
Part type menu
Previous screen

FIG. 21

FIG. 22


Microsoft Access-[Plating]
File Edit View Records Window Help
Painting
Mask/demask
Marking
Heat treat
Alodine
Anodize
Passivate
Plating
Plating Material
Aluminum IVD MIL-C-83488 (F-694)
Cadmium QQ-P-416 (F-046)
Chromium QQ-C-320 (F-045)
Copper MIL-C-14550 (F-041)
Electroless Nickel MIL-C-26074 (F-038)
Gold plating MIL-G-45204 (F-039)
Nickel plating QQ-N-290 (F-042)
Nickel strike None (F-019)
Silver plating QQ-S-365 (F-040)
Tin plating MIL-T-10727 (F-048)
Tin, hot dipped MIL-T-10727,II (F-047)
Tin, immersion MIL-T-81955 (F-352)
Zinc plating ASTM B633 (F-084)
Polyester impregnate MIL-STD-276,I (F-074)
Anaerobic impregnate MIL-STD-276,II (F-074)
Miscelaneous
Different substrate alloys
Crevices/blind holes <.060"
Thru plated holes <.060"
Post plated dim's < +/-.001
Poor part drainage
Leak test required
Corrosion resistance tests
Wear resistance tests
Solderability tests
Electrical conductivity tests
Non-magnetic tests
Pieces welded or fastened
Cube size
1/2" cube
12" cube
6" cube
12"+cube
$32ea.
σ
2.5 days
99%
Cost, quality, ct of finish process
Plating process
Main menu
Part type menu
Previous screen

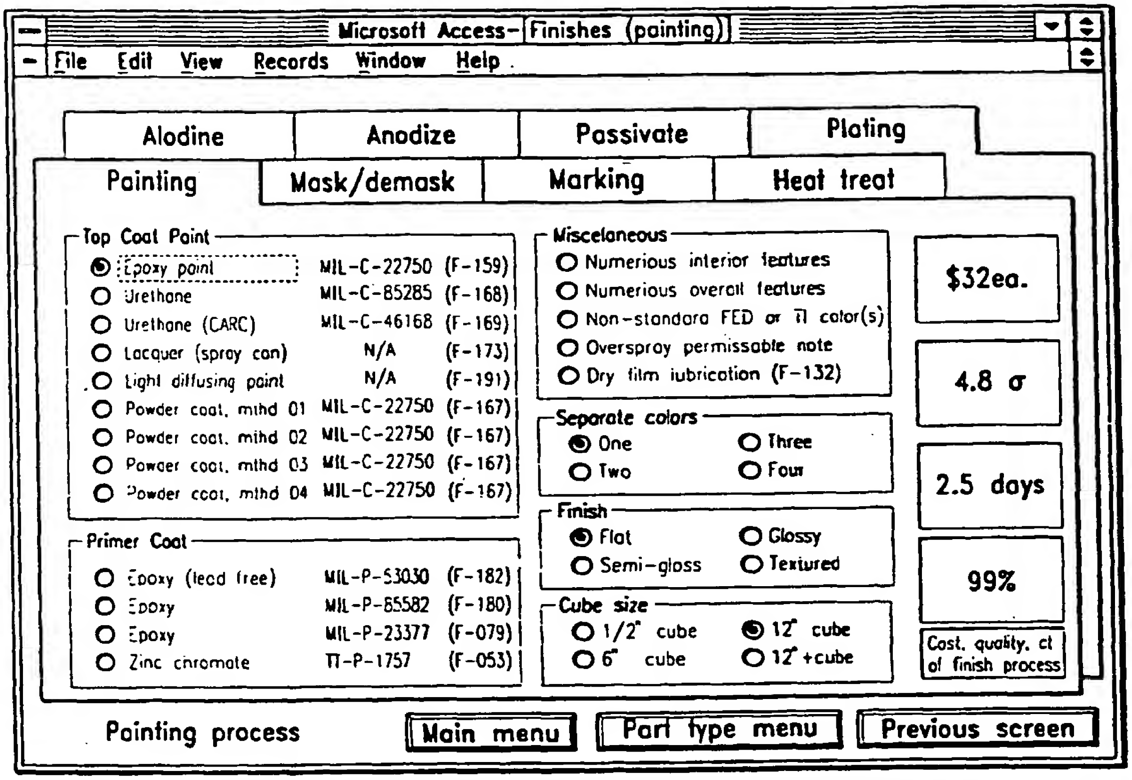
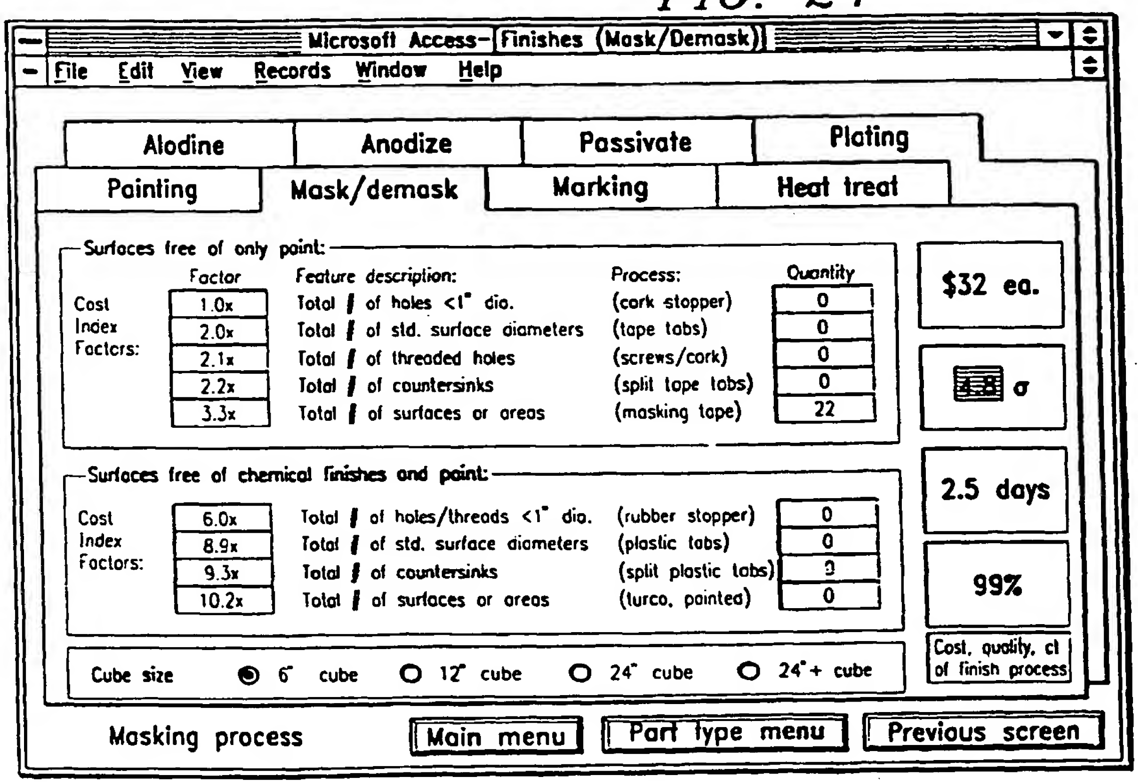

Microsoft Access-[Finishes (painting)]
File Edit View Records Window Help
Alodine
Anodize
Passivate
Plating
Painting
Mask/demask
Marking
Heat treat
Top Coat Paint
Epoxy paint MIL-C-22750 (F-159)
Urethane MIL-C-85285 (F-168)
Urethane (CARC) MIL-C-46168 (F-169)
Lacquer (spray can) N/A (F-173)
Light diffusing paint N/A (F-191)
Powder coat, mthd 01 MIL-C-22750 (F-167)
Powder coat, mthd 02 MIL-C-22750 (F-167)
Powder coat, mthd 03 MIL-C-22750 (F-167)
Powder coat, mthd 04 MIL-C-22750 (F-167)
Primer Coat
Epoxy (lead free) MIL-P-53030 (F-182)
Epoxy MIL-P-85582 (F-180)
Epoxy MIL-P-23377 (F-079)
Zinc chromate TT-P-1757 (F-053)
Miscelaneous
Numerious interior features
Numerious overall features
Non-standard FED or TI color(s)
Overspray permissable note
Dry film lubrication (F-132)
Separate colors
One
Two
Three
Four
Finish
Flat
Semi-gloss
Glossy
Textured
Cube size
1/2" cube
6" cube
12" cube
12" +cube
$32ea.
4.8 σ
2.5 days
99%
Cost, quality, ct of finish process
Painting process
Main menu
Part type menu
Previous screen

FIG. 23

FIG. 24


Microsoft Access-[Finishes (Mask/Demask)]
File Edit View Records Window Help
Alodine
Anodize
Passivate
Plating
Painting
Mask/demask
Marking
Heat treat
Surfaces free of only paint:
Factor
Feature description:
Process:
Quantity
Cost Index Factors:
1.0x Total # of holes <1" dia. (cork stopper) 0
2.0x Total # of std. surface diameters (tape tabs) 0
2.1x Total # of threaded holes (screws/cork) 0
2.2x Total # of countersinks (split tape tabs) 0
3.3x Total # of surfaces or areas (masking tape) 22
Surfaces free of chemical finishes and paint:
Cost Index Factors:
6.0x Total # of holes/threads <1" dia. (rubber stopper) 0
8.9x Total # of std. surface diameters (plastic tabs) 0
9.3x Total # of countersinks (split plastic tabs) 0
10.2x Total # of surfaces or areas (turco, painted) 0
Cube size
6" cube
12" cube
24" cube
24"+ cube
$32 ea.
4.8 σ
2.5 days
99%
Cost, quality, ct of finish process
Masking process
Main menu
Part type menu
Previous screen

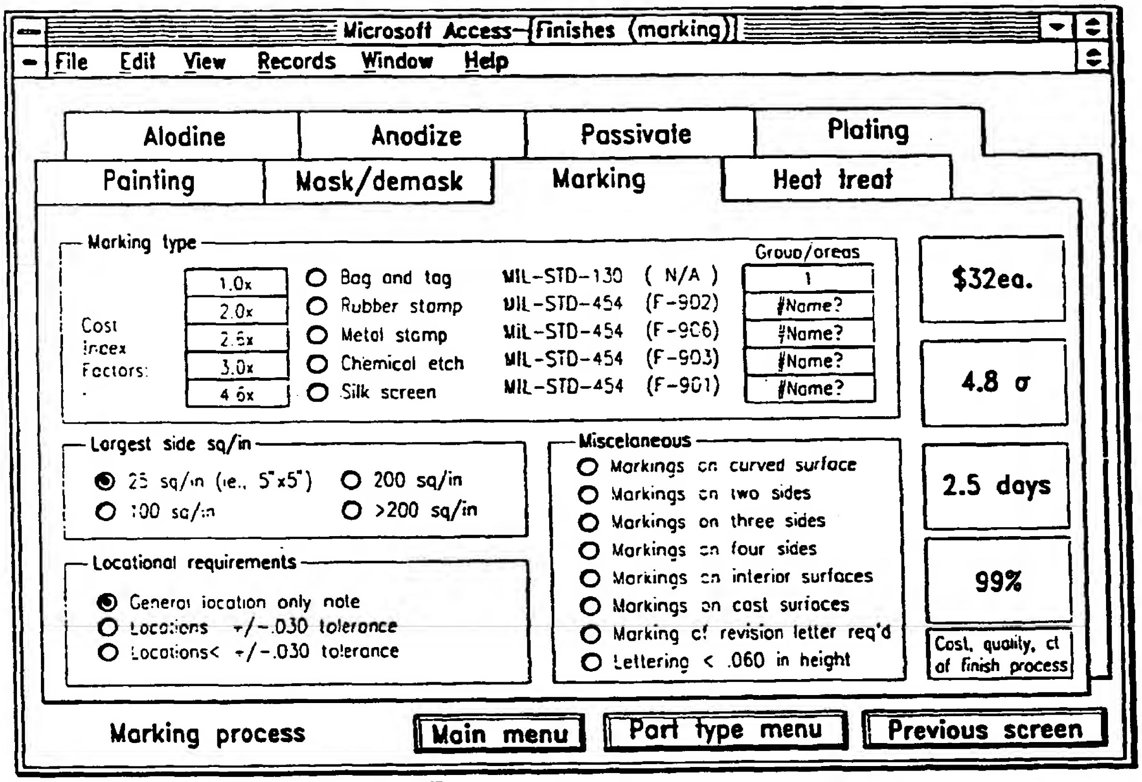
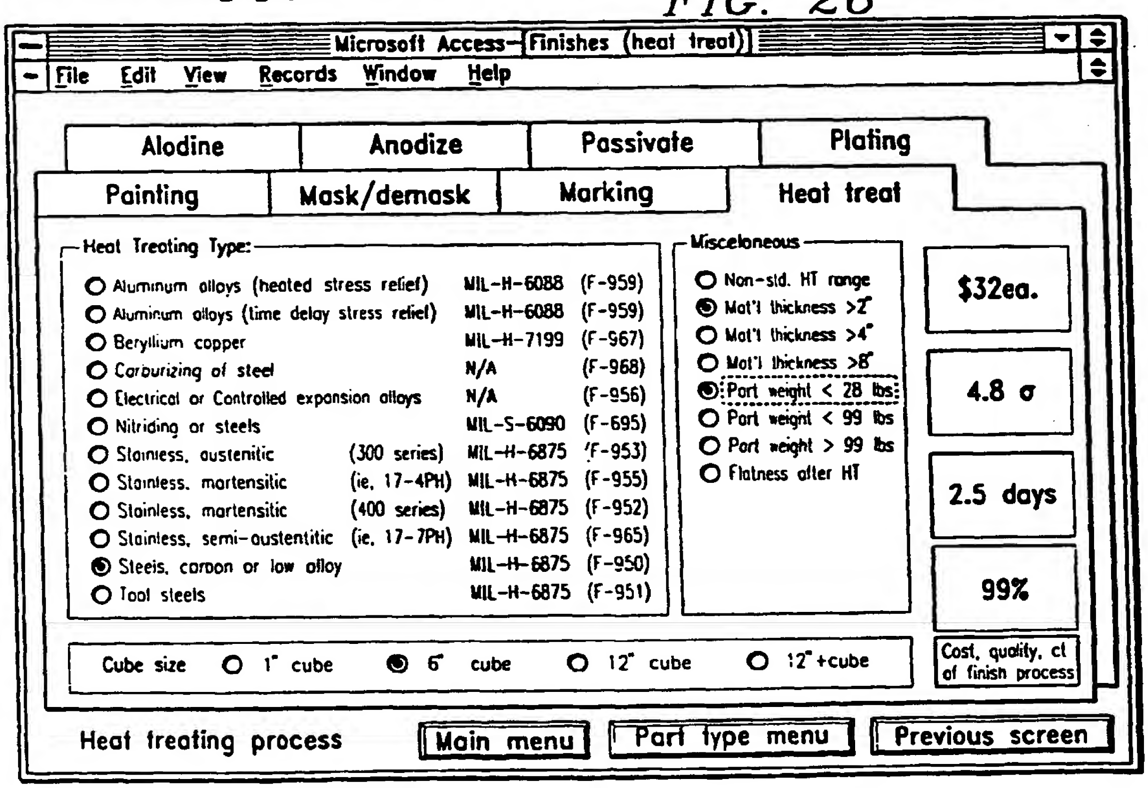

Microsoft Access–[Finishes (marking)]
File Edit View Records Window Help
Alodine
Anodize
Passivate
Plating
Painting
Mask/demask
Marking
Heat treat
Marking type
Cost Index Factors:
1.0x
2.0x
2.5x
3.0x
4.6x
Bag and tag MIL-STD-130 (N/A)
Rubber stamp MIL-STD-454 (F-902)
Metal stamp MIL-STD-454 (F-906)
Chemical etch MIL-STD-454 (F-903)
Silk screen MIL-STD-454 (F-901)
Group/areas
1
#Name?
#Name?
#Name?
#Name?
$32ea.
4.8 σ
2.5 days
99%
Cost, quality, ct of finish process
Largest side sq/in
25 sq/in (ie., 5"x5")
200 sq/in
100 sq/in
>200 sq/in
Locational requirements
General location only note
Locations +/-.030 tolerance
Locations< +/-.030 tolerance
Miscelaneous
Markings on curved surface
Markings on two sides
Markings on three sides
Markings on four sides
Markings on interior surfaces
Markings on cast surfaces
Marking of revision letter req'd
Lettering < .060 in height
Marking process
Main menu
Part type menu
Previous screen

FIG. 25

FIG. 26


Microsoft Access–[Finishes (heat treat)]
File Edit View Records Window Help
Alodine
Anodize
Passivate
Plating
Painting
Mask/demask
Marking
Heat treat
Heat Treating Type:
Aluminum alloys (heated stress relief) MIL-H-6088 (F-959)
Aluminum alloys (time delay stress relief) MIL-H-6088 (F-959)
Beryllium copper MIL-H-7199 (F-967)
Carburizing of steel N/A (F-968)
Electrical or Controlled expansion alloys N/A (F-956)
Nitriding of steels MIL-S-6090 (F-695)
Stainless, austenitic (300 series) MIL-H-6875 (F-953)
Stainless, martensitic (ie, 17-4PH) MIL-H-6875 (F-955)
Stainless, martensitic (400 series) MIL-H-6875 (F-952)
Stainless, semi-austentitic (ie, 17-7PH) MIL-H-6875 (F-965)
Steels, carbon or low alloy MIL-H-6875 (F-950)
Tool steels MIL-H-6875 (F-951)
Miscelaneous
Non-std. HT range
Mat'l thickness >2"
Mat'l thickness >4"
Mat'l thickness >8"
Part weight < 28 lbs
Part weight < 99 lbs
Part weight > 99 lbs
Flatness after HT
$32ea.
4.8 σ
2.5 days
99%
Cost, quality, ct of finish process
Cube size
1" cube
6" cube
12" cube
12"+cube
Heat treating process
Main menu
Part type menu
Previous screen

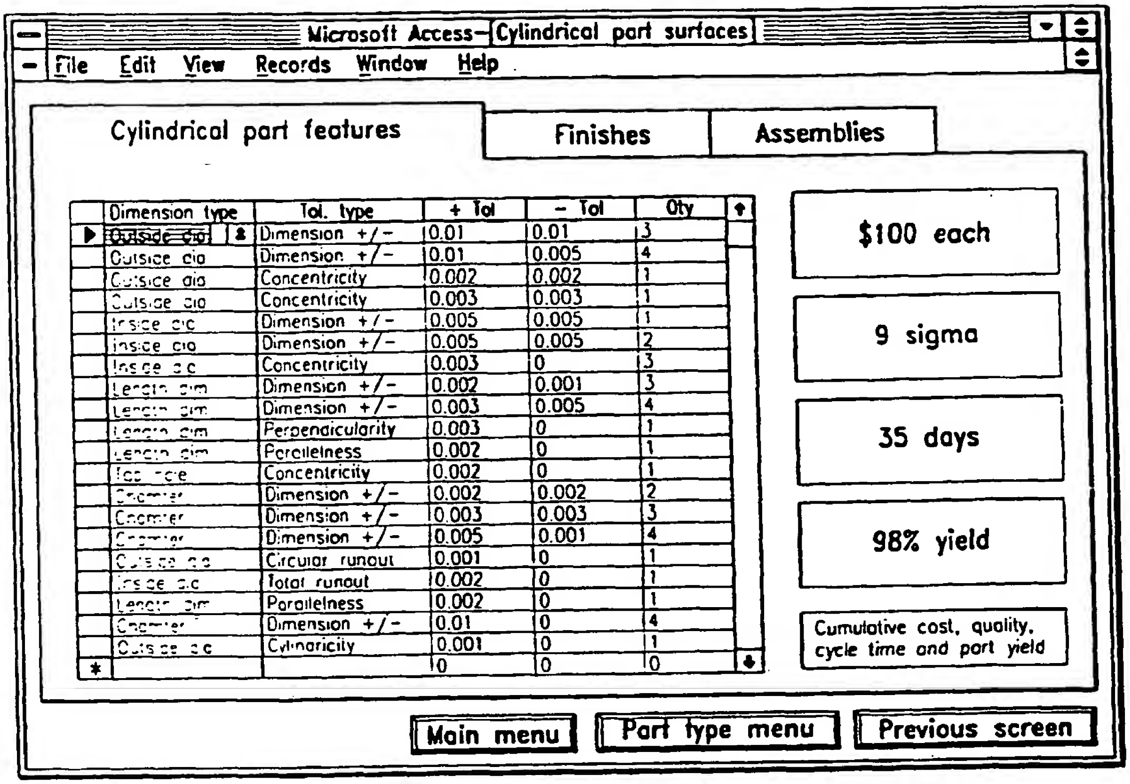
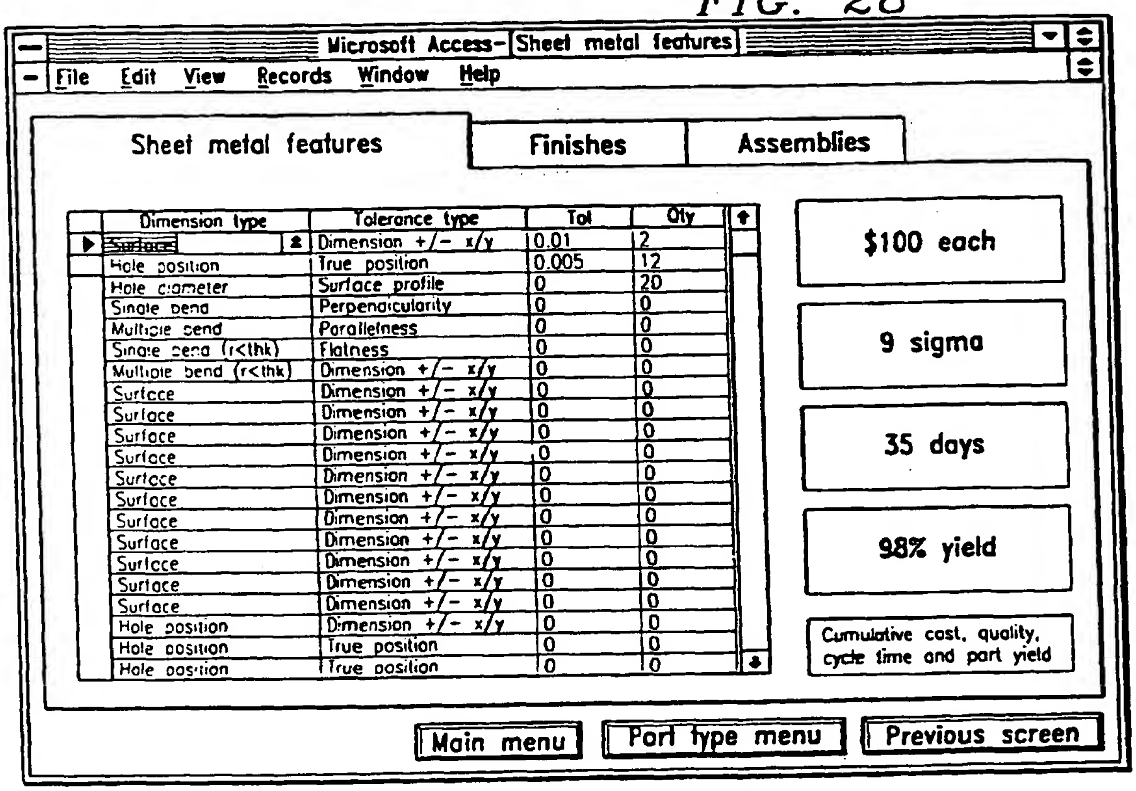

Microsoft Access-Cylindrical part surfaces
File Edit View Records Window Help
Cylindrical part features
Finishes
Assemblies
Dimension type
Tol. type
+ Tol
- Tol
Qty
Outside dia
Dimension +/-
Concentricity
Perpendicularity
Parallelness
Circular runout
Total runout
Cylindricity
$100 each
9 sigma
35 days
98% yield
Cumulative cost, quality, cycle time and part yield
Main menu
Part type menu
Previous screen

FIG. 27

FIG. 28


Microsoft Access-Sheet metal features
File Edit View Records Window Help
Sheet metal features
Finishes
Assemblies
Dimension type
Tolerance type
Tol
Qty
Surface
Hole position
Hole diameter
Single bend
Multiple bend
Single bend (r<thk)
Multiple bend (r<thk)
Dimension +/- x/y
True position
Surface profile
Perpendicularity
Parallelness
Flatness
$100 each
9 sigma
35 days
98% yield
Cumulative cost, quality, cycle time and part yield
Main menu
Part type menu
Previous screen

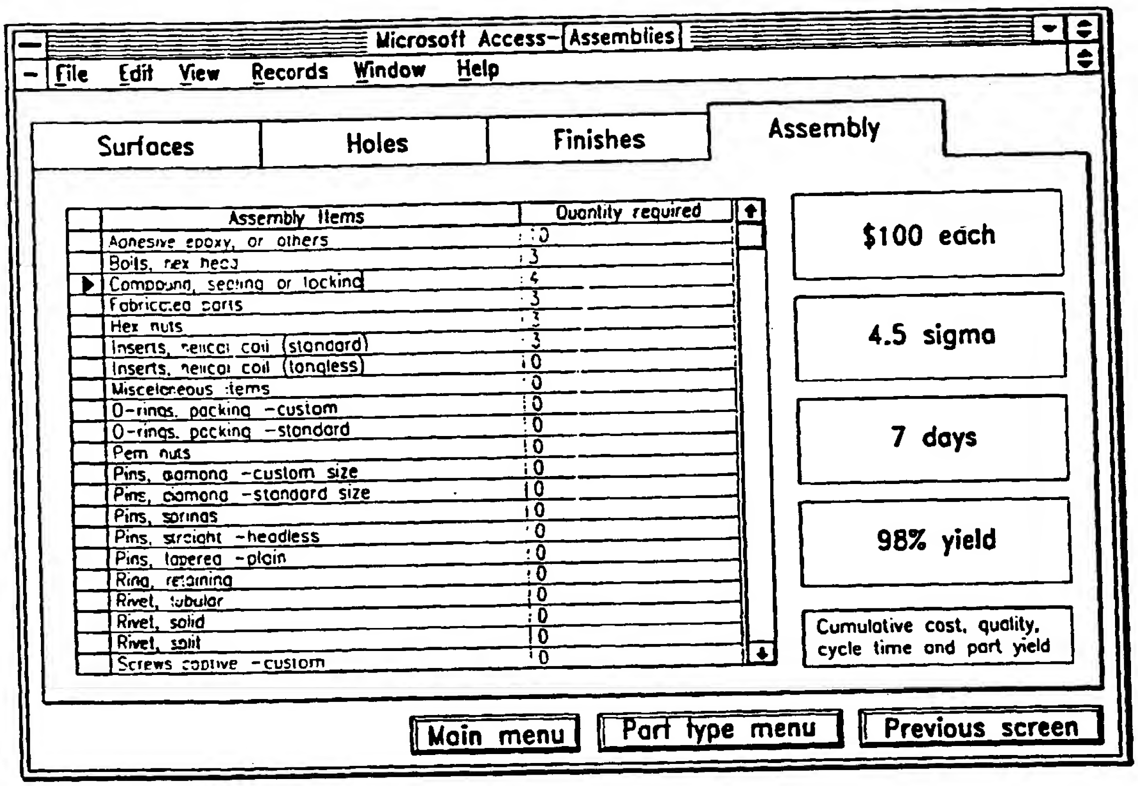

Microsoft Access-Assemblies
File Edit View Records Window Help
Surfaces
Holes
Finishes
Assembly
Assembly Items
Quantity required
Adhesive epoxy, or others
Bolts, hex head
Compound, sealing or locking
Fabricated parts
Hex nuts
Inserts, helical coil (standard)
Inserts, helical coil (tangless)
Miscellaneous items
O-rings, packing -custom
O-rings, packing -standard
Pem nuts
Pins, diamond -custom size
Pins, diamond -standard size
Pins, springs
Pins, straight -headless
Pins, tapered -plain
Ring, retaining
Rivet, tubular
Rivet, solid
Rivet, split
Screws captive -custom
$100 each
4.5 sigma
7 days
98% yield
Cumulative cost, quality, cycle time and part yield
Main menu
Part type menu
Previous screen

FIG. 29

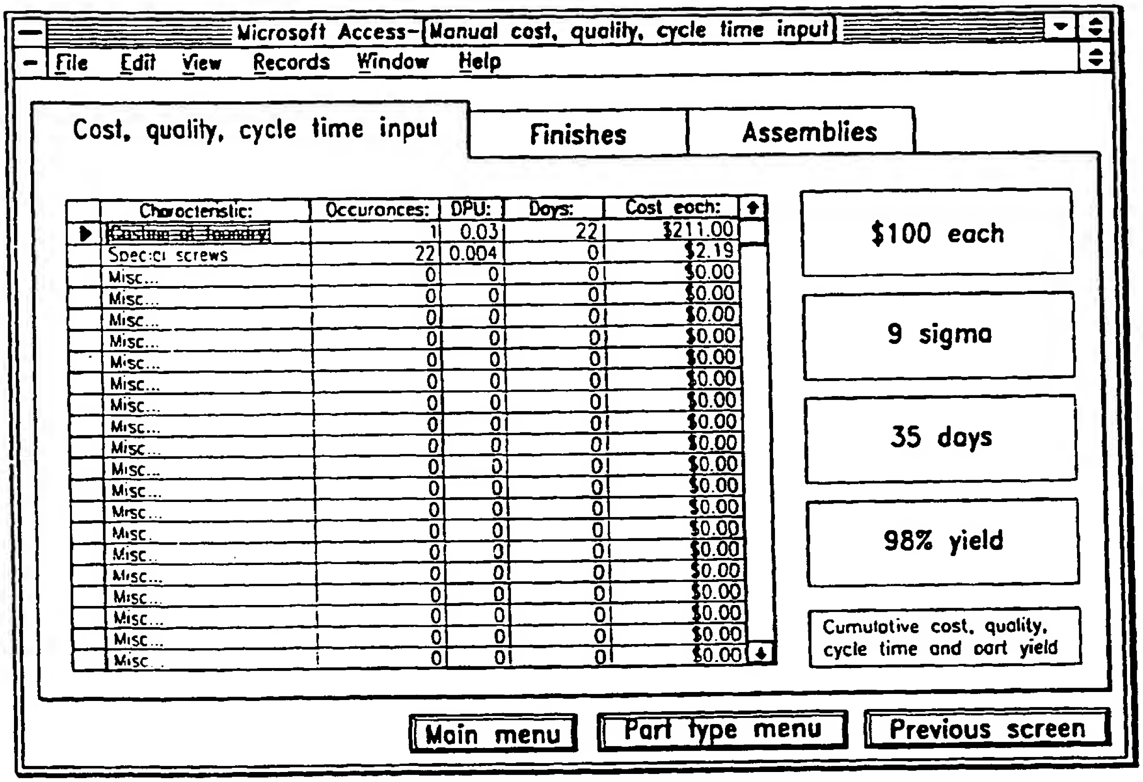

Microsoft Access-Manual cost, quality, cycle time input
File Edit View Records Window Help
Cost, quality, cycle time input
Finishes
Assemblies
Characteristic: Occurances: DPU: Days: Cost each:
Casting of foundry 1 0.03 22 $211.00
Special screws 22 0.004 0 $2.19
Misc... 0 0 0 $0.00
$100 each
9 sigma
35 days
98% yield
Cumulative cost, quality, cycle time and part yield
Main menu
Part type menu
Previous screen

FIG. 30

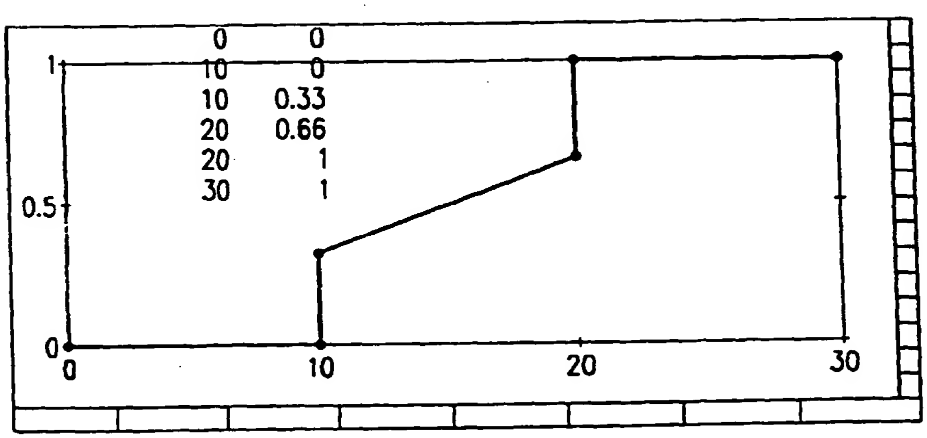

0 0
10 0
10 0.33
20 0.66
20 1
30 1
1
0.5
0
0
10
20
30

FIG. 31

(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 811 941 A3

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(51) Int. Cl.[6]: G06F 17/50

(43) Date of publication A2:
10.12.1997 Bulletin 1997/50

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(54) **A capability predictor**

(57) A capability predictor that comprises a database 15 of capability of multiple designs is disclosed. The process capability data includes costs, quality, cycle time, and performance models. The process owner (expert) provides the data. The developer inputs equations necessary to calculate the predictions based in the selected design characteristics and the user selects the design. A processor 11 calculates the prediction based on the selected design and a display, such as monitor 11a or printer 16, displays the results of the predictions.

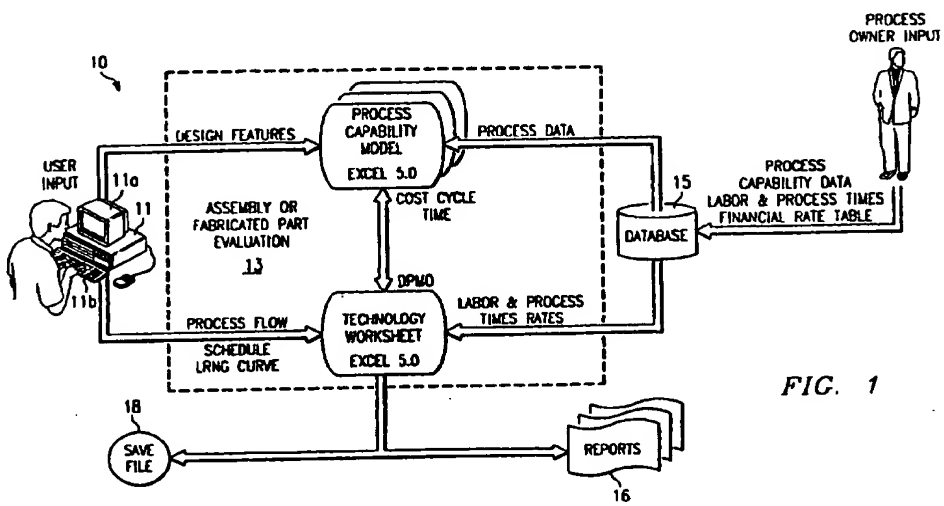

FIG. 1

EP 0 811 941 A3

European Patent Offic

EUROPEAN SEARCH REPORT

Application Number
EP 97 10 8457

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
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CATEGORY OF CITED DOCUMENTS

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02-06-1999

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82